JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. CIII. JUNE, 1877. No. 6.

EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Committee on Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

Franklin Institute.

HALL OF THE INSTITUTE, May 16th, 1877.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 149 members and 20 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers and reported that at the last meeting 19 persons were elected members of the Institute; that on the recommendation of the Committee on Science and the Arts, the Board awarded the Elliott Cresson Gold Medal to Mr. P. H. Dudley, for his Dynograph for measuring and graphically recording Railway Resistances; and that the following donations were made to the library:

Catalogue of the University of Penna. 1876-77. From L. M. Haupt, Prof. Civil Eng.

Brazilian biographical annual, by J. Manuel de Macedo. Vols. 1–3. Rio de Janeiro, 1876. From the Smithsonian Institution.

Sixty numbers of the JOURNAL OF THE FRANKLIN INSTITUTE, from 1871-75 incl. From Wm. P. Tatham. Philad.

Bulletin of the United States Geological and Geographical Survey of the territories. Vol. 3, No. 1. Wash., April 5, 1877. From the Department of the Interior.

Annual report of the chief of the bureau of statistics on the commerce and navigation of the United States. 1861–63 and 1865–75 incl. Wash. From Hon. Chas. O'Neil, House Rep.

Dana's text book of mineralogy with an extended treatise on crystallography and physical mineralogy. N. Y., 1877.

Elements of geometry, by G. M. Searle, with an appendix containing problems and additional propositions. N. Y., 1877. From Wiley & Sons, N. Y.

Hydraulics of great rivers, by Révy, J. J. London, 1874. From the Friends' Library, Germantown, through their librarian, Wm. Kite.

Specifications and drawings of Patents issued from the United States Patent Office, for October, 1876. Wash., 1877. Report of the Com. of Pat. for the year 1863. Vol. 1. Wash., 1866. From the U. S. Patent Office.

Contributions to the Centennial Exhibition, by John Ericsson. N. Y., 1876. From the author.

Foundation of the Washington National Monument, Reports on. From the Engineers' Office.

Quarterly weather report of the Meteorological Office. Pt. 3. 1874. London, 1877. Charts of meteorological data for nine Ten degree squares. Lat. 20° N. to 10° S., Long. 10° to 40° W. Remarks to accompany the above. From the Meteorological Committee, London.

Chemical and physical researches, by Thos. Graham. Edinburgh, 1876. From Young & Smith. Edinburgh.

The Secretary reported from the Committee on Science and the Arts, that at its last meeting it recommended the award of the Scott Legacy Premium and Medal to Thos. Shaw, for his spiral exhaust nozzle; and the Elliott Cresson Gold Medal to John Charleton, for his internal clamp coupling.

The Secretary presented his report, embracing the following subjects: an illustrated description of the Steam Street Car invented by Mr. Louis Ransom (Troy, N. Y.), six of which are now running on the Market Street line in this city; films of gold, prepared by Mr.

A. E. Outerbridge, having the extraordinary thinness of about one-three millionth of an inch; examples of remarkable corrosion of the propellor blades of Trans-atlantic steamers; the Edson electric pen and duplicating press; Russell's parallel pliers; J. B. Shannon's bran duster; J. W. Moyer's adjustable bed bottom, and a note from Mr. H. W. Pond, upon the sticking fast of the safety valve of a steam boiler under peculiar circumstances.

The Secretary read a letter from Mr. A. T. Goshorn, Director General of the late Centennial Exhibition, conveying a copy of the Report of the Judges, upon which a medal was awarded to the Institute "for its interesting exhibition, and for its valuable contributions to the progress of the Arts and Sciences."

The following letter, referred to this meeting by the Board of Managers, was read:

FRANKFORD, April 20th, 1877.

FRED'K FRALEY, Esq.

My Dear Sir:—I am permitted by my nephews, John and William Struthers, to present to the Franklin Institute a marble bust of William Strickland, deceased, who was (I am informed) the first secretary of the Institute. My father and Mr. Strickland were co-workers and life-long friends, and both among the early promoters of the Institute. I now desire that these memorials[1] of them, should become the property, and remain together in keeping of the Institute, which they, when living, so highly esteemed. Will you be kind enough to request the acceptance of the bust by the Board of Managers?

Yours, very respectfully,

JOHN STRICKLAND STRUTHERS.

On motion of Mr. Hector Orr it was

Resolved, That the gift to the Institute, by Mr. John Strickland Struthers, of the bust of the late William Strickland, Esq., be gratefully accepted, and the Board of Managers be requested to make such arrangements as may be necessary to receive and care for the same.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

Cosmical Dust.—M. Daubrée accounts for the smoky or dusty clouds, which often remain after the disappearance of meteors, and for the masses of dust which often pervade the atmosphere, by explosive action under great pressure. C.

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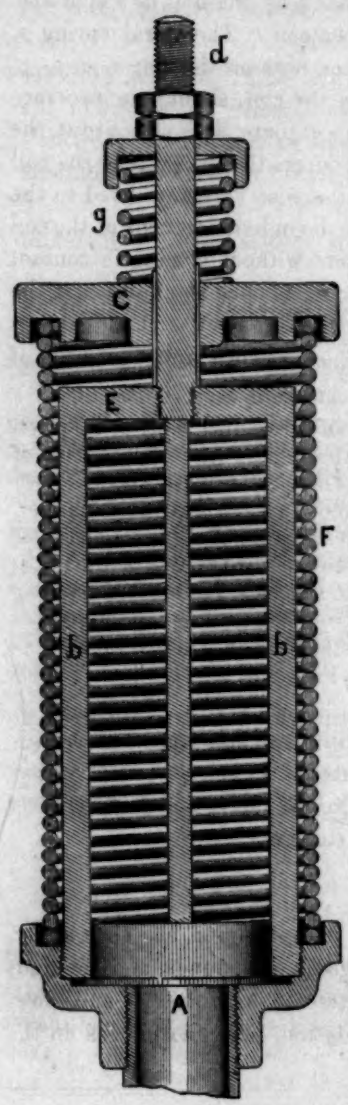
[1] See minutes of Dec. 20th, 1876, p. 9, this vol.

SHAW'S SPIRAL EXHAUST NOZZLE.

Extract from the Secretary's Report, at the Meeting of the Franklin Institute, Feb. 21st, 1877.



The great danger and annoyance arising from the safety valves of locomotives and steamboats are familiar to all, and are often so great as to imperil life as well as property.

When a train of cars is standing at a station, the roar of the safety valve is so deafening that it prevents the rapid transaction of business, and causes great annoyance and fright to passengers.

When a tug-boat is going alongside of a vessel to make fast, or is making a landing with a vessel, the stopping of the engines necessitates the raising of the safety-valve, and the escaping steam produces such a howl that orders cannot be heard, and, consequently, not executed with that promptness necessary to safety.

Especially is this the case with vessels in foggy weather, when listening for sound signals from shore, or in case of threatened collision, when a few moments' delay may cost lives, as well as loss of property.

The spiral exhaust nozzle of Mr. Thos. Shaw, is intended to quiet all this noise, while allowing the free escape of steam.

The construction of the nozzle will be easily understood by referring to the accompanying cut, which shows a

vertical section through the centre. *F* is a cylindrical coil of wire of such diameter and length that, when compressed nearly to contact, the aggregate area of the spaces between the turns of the coil, is much greater than that of the escape pipe. The bars *b b*, support the coil in a vertical position, between two plates *A* and *C*, and it is held in compression, nearly to contact, by the bolt *d*, which also admits of adjustment of the spaces in the coil. The spiral spring *g*, is introduced between the plate *C* and the nuts on the bolt *d*, so as to permit a slight increase of the spaces in the coil, should the pressure on its interior become too great. The base plate *A*, is attached to the end of the pipe through which the steam enters the nozzle, and the coil takes up the vibrations, which would otherwise be transmitted to the air by the escaping steam. As, however, the individual turns of the coil cannot vibrate to any considerable extent without coming in contact with the adjacent ones, interference occurs to such an extent that the vibrations are not transmitted to the air.

A report adopted by the Committee on Science and the Arts, of the Franklin Institute, says:

"We have examined the apparatus and tested its merits, in quiet-
"ing the noise produced by steam escaping from the safety-valves of
"boilers, and find that it accomplishes the object most effectively;"
and concludes: "In view of the annoyance, fright and danger,
"arising from the roar of escaping steam, and of the completeness
"with which the nozzle destroys this roar, we are of the opinion that
"Mr. Shaw has done a great service to the community, and particu-
"larly to the transportation interests, in overcoming an obnoxious
"and dangerous feature in the use of steam; and we recommend the
"award to him of the Scott Legacy Premium and Medal, for his
"spiral exhaust nozzle."

This nozzle is strongly indorsed, and its use recommended, by the Board of Supervising Inspectors of steam vessels, by owners and captains of tug-boats, and engineers in the navy, and has recently been fitted to all the American line of steamers. K.

Organic Phosphorescence.—M. T. L. Phipson has been studying the phosphorescence of various organic compounds, and he finds that *noctilucine*, a nitrogenous body extracted from fireflies and glow-worms, becomes luminous by slow oxidation, like phosphorus in the mineral kingdom. C.

TRANSPARENT GOLD.

Extract from the Report of the Secretary, at the Meeting of the Franklin Institute, May 16th, 1877.

In the course of a lecture on gold, delivered before the Franklin Institute, on February 27th last,[1] Mr. A. E. Outerbridge, Jr., of the Assay Department of the Mint in this city, gave an account of some experiments he had made, with the view of ascertaining how thin a film of gold was necessary to produce a fine gold color.

The plan adopted was as follows: From a sheet of copper rolled down to a thickness of $\frac{5}{1000}$ of an inch he cut a strip $2\frac{1}{2}$ by 4 inches. This strip, containing 20 square inches of surface, after being carefully cleaned and burnished, was weighed on a delicate assay balance. Sufficient gold, to produce a fine gold color, was then deposited on it by means of the battery; the strip was then dried without rubbing, and re-weighed, and found to have gained one-tenth of a grain, thus showing that one grain of gold can, by this method, be made to cover 200 square inches, as compared to 75 square inches by beating.

By calculation, based on the weight of a cubic inch of pure gold, the thickness of the deposited film was ascertained to be $\frac{1}{980400}$ of an inch, as against $\frac{1}{367650}$ for the beaten film.

An examination under the microscope, showed the film to be continuous and not deposited in spots, the whole surface presenting the appearance of pure gold.

Not being satisfied, however, with this proof, and desiring to examine the film by transmitted light, Mr. Outerbridge has since tried several methods for separating the film from the copper, and the following one has proved entirely successful:

The gold plating was removed from one side of the copper strip, and by immersing small pieces in weak nitric acid, for several days, the copper was entirely dissolved, leaving the films of gold, intact, floating on the surface of the liquid. These were collected on strips of glass, to which they adhered on drying, and the image of one of them is here projected on the screen, by means of the gas microscope.

You will observe that it is entirely continuous, of the characteristic bright green color, and very transparent, as is shown by placing

[1] See JOURNAL OF THE FRANKLIN INSTITUTE, Vol. ciii, p. 281.

this slide of diatoms behind the film. By changing the position of the instrument, and throwing the image of the film on the screen by means of reflected light, as is here done, you will see its true gold color.

Mr. Outerbridge has continued his experiments, and, by the same processes, has succeeded in producing continuous films, which he determined to be only the one-two million seven hundred and ninety-eight thousandth ($\frac{1}{2\,798\,000}$) of an inch in thickness, or ten thousand five hundred and eighty-four (10,584) times thinner than an ordinary sheet of printing paper, or sixty (60) times less than a single undulation of green light. The weight of gold covering 20 square inches is, in this case, thirty-five-thousandths ($\frac{35}{1000}$) of a grain; one grain being sufficient to cover nearly 4 square feet of copper.

As you see, the film is perfectly transparent and continuous, even in thickness, and presents all the characteristics of the one shown before. That a portion of the image appears darker, is due to superposed films, the intensity of the green color being proportioned to the thickness through which the light passes.

These experiments will give new interest to the question of the cause of gold appearing green by transmitted light. K.

White Cement.—Herr O. Fahnejelm recommends a mixture of 75 parts of carefully washed chalk and 25 parts of washed kaolin, to be first calcined to red heat and afterwards ground. The powder is then snow-white, or, if the heat has been too great, it has a bluish shade. Either alone, or with a small percentage of gypsum, it makes an excellent hydraulic cement.—*Dingler's Polyt. Jour.*, 223, 3. C.

Secondary Elasticity.—In a late number of *Poggendorff*, Ferdinand Braun[1] reports a series of experiments with metallic rods, wires, threads and gums, in continuation of the experiments of Weber, Kohlrausch and Boltzmann, upon the after effects of elasticity. The independent and combined influences of bending, tension and stretching are investigated at considerable length, the results presented in eighteen tables, and a variety of fundamental propositions deduced which seem likely to have important bearings in chemical and other molecular investigations. C.

[1] *Ueber die Natur der elastischen Nachwirkung.*

Mechanical Stoking.—A paper was recently read at the Society of Engineers by Mr. J. Walter Pearse on the "Mechanical Firing of Steam Boilers." The author first pointed out some of the disadvantages of hand-stoking, and observed that so far back as 1813, mechanical firing was proposed. In 1822, Mr. J. Stanley invented a stoker with crushing and rollers a single horizontal fan, to which, in 1834, he added rocking fire-bars. In 1838, Mr. Juckes patented his first stoker, and in 1841, he invented the endless chain of fire-bars, modifying it again in 1842. In 1863, Messrs. Wilson and Smith brought out their furnace, in which the fire-bars were made to travel backwards, carrying the fuel from a hopper to the back of the grate, an arrangement which was improved upon by Messrs. Vicars and Smith in 1867. In 1870, Mr. Dillwyn Smith patented his stoker, in which the fuel is fed on to distributing fans revolving horizontally. This arrangement was improved upon, in 1870, by Mr. J. F. Deacon. Further additions were subsequently made by Mr. T. Henderson. In the Henderson stoker the supply of fuel is effected in the same way as in the Dillwyn Smith machine, but the fire-bars are made to move by simple gear connected with the stoker. Every other bar rises and falls, while the rest slide to and fro, the effect of this action being to clear off the clinker. The Frisbie feeder improved by Mr. J. M. Holmes, is for slow combustion and intermittent feed. The coal is thrust up underneath, and in the middle of the fire, so that the gases evolved are consumed on passing through the incandescent mass. This stirs the fire and propels all clinker to the circumference of the circular revolving grate. Mr. Holroyd Smith's "Helix" fire-feeder gives a continuous feed from below, by means of a screw working in a casing connected at its upper side with a trough which takes the place of one or two fire-bars.—*Journal of the Society of Arts.*

Carbonic Acid in Sea-Water.—O. Jacobsen has found large quantities of carbonic acid in sea-water, which can be removed only incompletely and with great difficulty, even by heating in a vacuum. He attributes the fact to a peculiar action of the magnesium chloride and calcium carbonate which are dissolved in the water. C.

Zinc in Animals and Vegetables.—MM. G. Lechartier and F. Bellamy have found zinc in the liver of men and calves, in beef, in hens' eggs, and in the grains of wheat, barley, maize, beans and lentils. C.

DIVISIBILITY OF ELECTRIC LIGHT.

By MM. L. Denayrouze and P. Jablochkoff.

Although the invention of M. Paul Jablochkoff has been in continual progress since the first communication which I had the honor of presenting to the academy, I have thought fit to wait before calling further attention to our studies, until a decisive application should have publicly and practically shown:

1. That the fixed light (*bougie*) could advantageously replace the regulator. 2. That it is possible to obtain by this process, many luminous centres with a single source of electric currents.

We have just established these points beyond controversy, by lighting, with multiple centres, every evening of the past week, one of the principal halls of the Louvre.

After this public verification of the principle submitted to the academy, I venture to announce the important result lately obtained by M. Jablochkoff, during some months of investigations, pursued in the workshops of the society which I direct.

From the first experiments upon the fixed light, we perceived that if we obtained by its means a steadier light than with the regulator, and if we could at the same time produce many illuminating centres, this double result was due to the action of the current upon the insulating material interposed between the two carbon points. The voltaic arc, by fusing this substance, established, for the current, a much easier passage between the points than when the insulator was solid. Experiment showed that when a certain tension was given to the current, the distance that the current could leap over this sort of liquid conductor, became sufficient to produce a considerable number of illuminating centres. We have thus obtained as many as eight bougies burning at once in the circuit of a single machine, with reciprocating currents, of the most ordinary type.

M. Jablochkoff then tried the effect of sparks, produced by a current of great tension, upon refractory bodies.

He introduced in the central circuit of the machine, the interior wire of a series of induction coils, and caused the spark from the induced current to pass over a sheet of kaolin, placed between the two extremities of the exterior wire of each coil.

We then saw that, although the current had not enough intensity to melt the interposed kaolin, it heated it to incandescence.

The current is first made to pass over a better conductor, arranged on the edge of the kaolin sheet. The part of the plate which is thus heated, forms a line which becomes a conductor of great resistance, and which, upon the passage of a current of great tension, glows with the heat and emits a beautiful light. Over the whole length there is a slight consumption of kaolin, at the rate of about one millimetre per hour. There is thus formed, between the two extremities of the coil, a magnificent luminous band, which may reach a much greater length than the induction spark ordinarily produced by the same coil. But this luminous band, in place of being slightly luminous, like the induction spark, is a permanent focus, giving a light which is soft, and steadier than any other known light. Its power depends on the number of windings and the diameter of the wire employed in the coil.

As a large number of bobbins may be placed in the circuit, and as each bobbin may be divided into numerous sections separately illuminating kaolin bands of suitable length, we thus obtain a complete divisibility of the electric light. We can very easily get fifty luminous centres of a variable intensity.

In our experiments we employed bobbins of different sizes. The intensity of the focus corresponding to each one of them, varies naturally with the dimension of the bobbin. We scaled the intensities of the different foci, so as to have a graduated series of luminous bands, of which the most feeble give a light equivalent to one or two gas-burners, and the strongest a light of fifteen burners.

In employing the alternative currents, the break and the condenser may be suppressed; then the whole system of distribution of the currents is reduced to a central artery, represented by the series of interior wires of the bobbin, from which branch out as many distinct conductors as there are bobbins in the circuit. Each luminous centre is thus perfectly independent, and each of them may be extinguished or lighted separately. The distribution of electricity in a building which is to be lighted, becomes then analogous to the distribution of gas, and in the special factory which we are constructing, the largest rooms will be lighted by bougies, the offices and corridors by bands.

The following are the results which M. Jablochkoff has already attained: 1. Complete divisibility of the electric light. 2. Absolute

steadiness of this divided light. 3. Possibility of distributing in any proportions, and in any points of a place which is to be lighted, great, small or medium lights. 4. Dispensing with carbon points for the small and medium lights.—*Comptus Rendus*, April 16. C.

Action of Compressed Incandescent Gases.—M. Daubrée has been experimenting upon the combustion of powder in close vessels, obtaining results which seem to account for the alveolar surface of meteorites as well as for a variety of volcanic and other geological phenomena. A rectangular plate of steel having a surface of 23 square centimetres, and weighing 3·479 grammes, was placed in a closed vessel, which had a capacity of 43 c. centimetres. The plate was rolled so as to be completely surrounded by the gases which resulted from the explosion of the powder by the electric spark. The deflagration lasted less than ·02 of a second. The gases acquired a tension of from 1000 to 1500 atmospheres, according to the charge employed, and an estimated temperature of more than 2000° C. The cooling was equally rapid, on account of the enormous difference between the gaseous temperature and that of the walls. In an experiment with 12 grammes of powder, the steel plate was entirely melted, and transformed into a spongy ingot, curiously distorted and puffed up, like the ferruginous skeleton of some meteoric stones. At the same time, nearly a fifth of the iron was reduced to a sulphuret, in the form of an impalpable powder. When a small opening was made in the chamber, so that a portion of the gases could escape with great velocity, sinuous furrows were scooped out of the sides of the iron vessel, a second aperture of escape was made at about 50° from the first, and a quantity of irritating metallic dust, in an incandescent state, was forced into the atmosphere. The effects were comparable, in their nature, suddenness and energy, to those which are produced by a thunderbolt, or a powerful electric spark.—*Comptes Rendus*, Mar. 5, 1877. C.

Spectrum of Electric Light.—M. P. Desains finds that the spectra of electric light are very similar to those of the solar rays. They are less extensive, particularly on the side of the violet; but the curves of intensity exhibit but slight differences in the region of greatest heat. C.

Algeria.—The February number of the *Annales des Ponts et Chaussées*, contains an interesting article on the natural conditions, the system of colonization, and the public works of Algeria. The plantations are among the most important elements of colonization. When they are not absolutely indispensable for sanitary purposes, as at Boufarik, and in all the marshy districts, they are valuable for their shade. The magnificent promenades of Tlemcen, Sidi-Bel-Abbès, and Blidah, show what can be done under great discouragements. In all the province of Oran, a few points excepted, the soil has a depth of only 10 to 15 centimetres. Each tree costs about 6 francs, and 2 francs a year for watering and care. The kinds most used are the plane, the elm, the acacia and the pine. The eucalyptus is also used, but it succeeds only in thickets. The plane is the most desirable wherever there is a sufficient supply of running water; it gives the largest shade, and forms the most magnificent arcades. The elm requires less watering, but its growth is slow. The acacia grows more rapidly, and thrives with still less water, but it is brittle, and must be shielded from the winds. The Aleppo pine needs little care, but it cannot be used for the public promenades. It is only planted in thickets, or upon large surfaces. The mountain of Santa Cruz, at Oran, and the sand dunes of La Macta, have been successfully planted with pines. The principal fruit trees are the orange and the lemon; when well watered, their fruit is abundant, and larger, if less delicate, than those of Spain and Malta.

The public works, harbors, railroads, reservoirs, canals, highways, villages and plantations—and the guardianship of the colony until its majority—involve heavy charges. Africa costs more than it pays, but the profitable harvest may be near at hand. In 1830, Algeria was a land uncultivated, scantily supporting 3,000,000 inhabitants, without harbors, without roads, without water, continually wasted by famine and intestine wars. After a half century's occupation, thanks to European activity, improved culture, irrigation and safety of communication, barren steppes and uninhabitable bogs have been rendered wholesome, occupied and fertilized. Wheat, maize, tobacco, the vine and garden vegetables, have replaced the sterile palm-tree and the thorny jujube. The cost of living is only half as great as in France; the export, both of grain and of cattle, is considerable. The Arabs, divided, enclosed in the network of civilized centres, abandon the idea of resistance, and accept the neighborhood of the

infidel, which brings them security, the stir of business, and wants which require labor for their satisfaction.

The impression of a traveler who visits Algeria, is surprise; he is astonished at seeing France, with its inhabitants, its customs, and its very aspect, in a country which he expected to find purely Arabic. The time is not far distant when the colonists will have passed from their period of tutelage; then the charges will cease, and the product of the imposts, insufficient to-day, will increase in proportion to the rapid augmentation of the resources. The mother-country will be rewarded for her sacrifices. The austere definition of Sallust is no longer correct: by the omnipotence of labor and of science, the "inhospitable coast" has acquired harbors of refuge, the "cursed land" has been blessed with water and trees. It has become a part of France, and, perhaps, one of its richest districts. C.

Submarine Detonators.—In a report of Capt. Kunkler, on the successful removal of wrecks from the mouth of the Loire, the detonators are fully described. The primings were furnished by Capt. Putot, who prefers iridized platinum to pure platinum, because its coefficient of electric conductivity is, like that of most alloys, less variable with temperature. When the platinum thread is soldered in place, it is wrapped with a small tuft of dry gun-cotton, and the whole is protected by an envelope of paper glued on the stem of the primer. The battery liquid was a solution of 5 parts bisulphate and 1 part chloro-chromate of potash in 120 parts (by weight) of water, the solution being made at the moment of need. The liquid is poured into a cylindrical vessel of gutta-percha, of an interior diameter slightly greater than that of the gutta-percha plunger. As the plunger nearly fills the vessel, a small quantity of liquid suffices to moisten the zinc and carbon. The solution produces currents of about the same force as those of the sulphuric acid and bichromate of potash battery. Its only advantage is the dispensing with sulphuric acid, the transportation of which is always inconvenient. There were two failures—the first being due to the breakage of one of the wires, the second to a leakage, which was attributed to a softening of the rubber luting by exposure to heat. In the successful trial the joints were first luted with red lead, and then covered with leaf-rubber glued with liquid-rubber.—*Ann. des Ponts et Chaussées*, Feb., 1877. C.

Wood Preserved by Injecting Tannate of Iron.—M. Boris recommends Hatzfeld's process, which is based on an ingenious idea. The tannate of the protoxide of iron, which is soluble, absorbs oxygen rapidly from the air, and is transformed into insoluble tannate of peroxide. The operation is twofold: 1st, Injection of tannic acid; 2d, injection of a protoxide of iron. For this purpose pyrolignite is used, which combines the advantage of cheapness with that of not injuring the woody fibres. The injection is made in close vessels, with the same apparatus as for creosote. The inventor claims the following advantages: 1st, The complete insolubility of the tannate of peroxide, seems to give a complete guarantee of durability; 2d, the injection is so made as to yield a great excess of tannic acid, which, being free, coagulates the albumen of the wood, tanning it, so to speak, and transforming all woods into a kind of oak, very rich in tannic acid. C.

Reservoirs of the Rio Rimac.—The reservoirs are designed to prevent the havoc caused by the torrents during the rainy season, and to furnish a water supply, during the dry season, to the valleys and to the cities of Callao and Lima. They are situated in the cordillera of Huarochiri. They employ nine lagoons, at heights between 4287 and 4867 metres; but in spite of the great elevation the climate is so mild that the lagoons never freeze. The frequent alternations of frost and rain, the continual heavy thunder storms, the atmospheric oxidation of the rocks, the often terrible earthquakes, and the great danger which would result from the sudden precipitation of 36,000,000 cubic metres of water upon the city of Lima, forbade the employment of ordinary masonry for the dikes. A careful reconnoissance showed that it would be sufficient to make a narrow but deep trench for each of the lagoons, which could be closed by a metallic gate or dam supported at the sides by piers of masonry which are grooved into the living rock. The gate is formed of iron plates supported by horizontal beams. The difficulties of transportation require that none of the pieces shall weigh more than 150 kilogrammes. At the lower part of this metallic wall openings are made, bounded by squares in which the water gates play, under control of an operator at the top of the dam. The groove irons are Z shaped; the water gates are convex, to avoid too great thickness. All the iron, which is of the best quality, has been furnished by the Creusot workshops.

The piers are of cut stone, their dimensions varying with local circumstances. All the masonry has been very carefully executed. The stones are granitic, of large dimensions and so laid as to break joints in all directions. Native lime is used with Roman cement imported from England. The greatest depth of reservoir is 16·5 metres, the greatest capacity, 20,896,000 cubic metres. C.

Velocity of Light.—The 13th volume of the "Annales de l'observatoire de Paris," contains the memoir of M. Cornu on the determination of the velocity of light, embracing a complete recital of the experiments made in 1874 between the observatory of Paris and the tower of Montlhéry. Everything was done to obtain the greatest possible precision, by perfecting the method of the toothed wheel, which was devised by Fizeau in 1849. The method of observation, the construction of the various articles of apparatus and their mode of acting have been discussed in their most minute details, with a view to ascertain the causes of error, and to determine the most favorable conditions for their elimination. The agreement of results obtained under the most varied circumstances, shows the importance of this discussion. Care was taken in all cases to prove that the deviations followed the law of accidental errors, a verification which is commonly neglected, but without which the calculus of probabilities cannot be legitimately applied. The result of the experiments gives, for the velocity of light, 300,400 kilometres per second. This gives for the solar parallax, 8·88″, if we adopt Delambre's equation of light, (493·2″) or Bradley's constant of aberration, (20·25″), 8·80″, with Struve's constant, (20·445″).—*Les Mondes*, March 8; *Acad. des Sciences*, Feb. 26. C.

Pantopollite.—At the dynamite factory of Opladen, a cheap kind of dynamite is made which is called pantopollite. It contains a certain percentage of nitro-glycerine, dissolved in naphthaline, to prevent the production of troublesome nitric vapors at the time of the explosion. It has been tried at the mines of Friederichsthal, where the explosive effects were very satisfactory; but after the explosion, the fumes were so disagreeable that it was necessary to suspend the labor for some time, and the miners suffered from severe pains in the head and chest. Ten kilogrammes of pantopollite effected a more complete disaggregation, than thirty kilogrammes of common powder. C.

A New Kind of Nobili's Rings.—In *Poggendorff's Annalen* for November, 1876, J. Schiel[1] describes the formation of galvanic rings on a pure gold surface. In a small porcelain saucer, or in a watch glass, he places a small plate of absolutely pure gold, of about three centimetres diameter, and three grains weight. In its centre he puts a pointed platinum wire covered with lac or gutta percha, and connected with the positive electrode of from 4 to 8 galvanic elements, arranging an annular platinum wire around the gold plate, some millimetres higher. Filling the glass with distilled water, acidulated with a few drops of sulphuric or nitric acid, he connects the annular wire with the cathode, thus closing the circuit, and in a few minutes the gold plate takes a reddish color. Breaking the circuit after from 6 to 10 minutes he washes and dries the plate, which shows a number of palish concentric rings. If exposed for a few hours to direct sunlight, or to diffused light from 8 to 10 days, the rings assume a coloring, especially after the gradual exposure, of remarkable beauty and brilliancy. In the course of 6 or 8 weeks the colors are mostly changed into a dark bluish violet. If the gold contains the least portion of silver, the beauty of the rings is diminished, and they assume the violet hue. The central ring is commonly the most beautiful and characteristic. It exhibits, upon application of nitric acid, the whole spectrum, while the others show mostly only red, purple or green. By careful manipulation with an ivory spatula, the colors can often be changed, *e. g.*, from red to green, as if there were a green layer under the red. Similar, but less striking effects, may be produced with alkaline liquors. The play and changes of color which the rings give under the Nicoll's prism, are remarkably beautiful. Within twenty-four hours after the galvanic exposure of the plate, the polarized rings display their full brilliancy. C.

Marine Sounding-Line.—M. Ch. Tardieu employs a spherical envelope of caoutchouc, communicating with an iron reservoir by means of a small tube which is provided with a valve. The envelope being filled with mercury, any increase of external pressure forces into the reservoir some of the mercury, which cannot return on account of the valve. The weight of the mercury determines the pressure, and consequently the depth of the water. C.

[1] *Ueber das galvanische Verhalten des Goldes und eine neue Art Nobili'scher Ringe.*

Civil and Mechanical Engineering.

STEAM ON STREET RAILWAYS.

Extract from the Secretary's Report, at the Meeting of the Franklin Institute, April 18th, 1877.

At the stated meeting of the Franklin Institute, for April, 1877, the Secretary called attention to the growing importance of the subject of steam propulsion on street railways, and stated his intention to present and illustrate, from time to time, the progress being made towards the successful accomplishment of this desirable object. He proposed commencing with what is doing in our own vicinity, and gave the following statement (accompanied by illustrations on the screen) showing the part which Messrs. Burnham, Parry, Williams & Co., proprietors of the Baldwin Locomotive Works, of this city, have taken in connection with this subject; together with some data regarding the comparative cost of running street cars, in this city, by horses and by steam.

The demand for some motive power other than horses for this purpose, is becoming very general and emphatic. Not only is great interest manifested in the subject in all parts of our own country, but also in South America, the West Indies and in Europe, public attention is strongly turned in this direction.

The advantages to be gained by the use of steam are, greater economy in operation, and greater convenience to the public. The greater economy is expected from the fact demonstrated in every other business requiring power, that the most economical artificial power is derived from a steam boiler. The economy of steam on street railways, it is believed by some, has already been demonstrated by actual experience. Sufficient data have now been acquired to give actual figures on which to base a calculation. The superior advantages derived by the public from steam on street railways, will be, in the steam cars being more manageable than horse cars; in their occupying less space in the crowded streets of a

city; in their being able to make their trips in shorter time (and this without running at a greater speed than horse cars), owing to the fact that they can be stopped and started much more quickly; and from the fact that, when steam is used, the greater speed obtainable will bring suburban localities practically nearer business centres.

In 1875 the Baldwin Locomotive Works became so strongly convinced of the growing demand for a better motive power than horses on street railways, that they concluded to build, at their own cost and risk, an experimental steam street car. The car was finished in November, 1875, and the following cut faithfully represents its appearance. The City Councils of Philadelphia were applied to for

permission to try the car in this city, and under an ordinance passed by Councils, permission was given for a trial of the car for three days on the West End Railway, of West Philadelphia. The trial was accordingly made, and the car worked satisfactorily. As three days were too short a time for an exhaustive trial, the proprietors of the Baldwin Locomotive Works next proposed to Mr. William Richardson, President of the Atlantic Avenue Railway, of Brooklyn (where permission to try steam had already been given), for an experiment with the car on his line. The arrangement was perfected and the car sent to Brooklyn December 25th, 1875. It ran in Brooklyn from that time until June, 1876. One engineer ran the car and kept it in working order. Its consumption of fuel was between 7 and 8 pounds of coal per mile run. It drew regularly,

night and morning, an additional car, with passengers going into New York in the morning and returning at night. On several occasions, where speed was practicable, the car was run at the rate of 16 to 18 miles per hour.

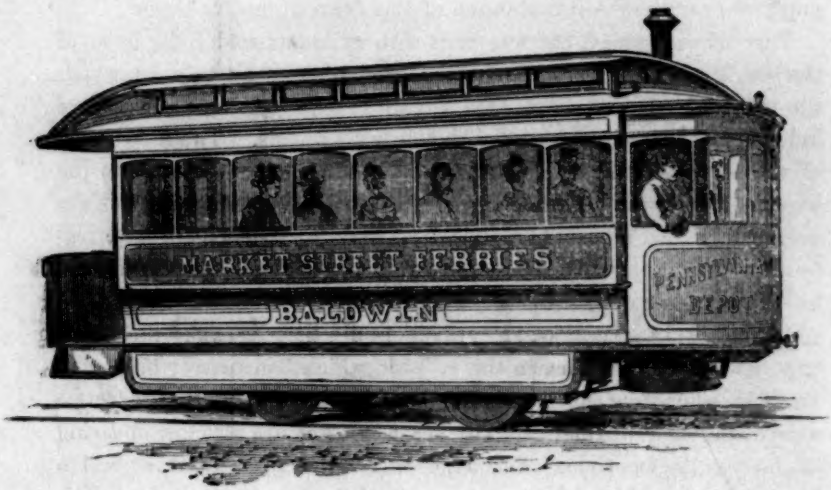
In June, 1876, this car was withdrawn from the Atlantic Avenue Railway of Brooklyn, and, by an arrangement with John S. Morton, Esq., President of the Market Street Railway, of Philadelphia, placed on that line. It worked with fair success and very acceptably to the public, on the Market Street line, from June till nearly the close of the Centennial Exhibition. Thousands of Centennial visitors were thus afforded an opportunity to witness the working of a steam car, and carried away impressions derived therefrom, which are doing much to promote the introduction of this form of motive power.

This original steam car was built with cylinders under the body of the car, the connecting-rods taking hold of a crank-axle, to which the front wheels were attached. The rear wheels of the car were independent, and not coupled with the front wheels. The machinery of the car was attached to an iron bed-plate bolted directly to the wooden framework of the car body. The experiment with this car demonstrated to the satisfaction of its builders, the entire practicability of the use of steam on street railways, but the defects developed by this experimental car were: first, that it was difficult, or impossible, to make a crank-axle which would not break; the same experience being reached in this respect, which had already presented itself in locomotive construction. Crank-axles in locomotive practice were abandoned in America many years ago, and are also disappearing in foreign locomotives. Second, it was found that great objection existed to attaching the machinery to the wooden car body, which was not sufficiently rigid for the purpose, and which suffered by being racked and strained by the working of the machinery.

For these reasons the builders removed this original steam car from the Market Street line in the fall of 1876, and placed it in their works to be re-constructed, in accordance with the experience which nearly a year's service had suggested. In order to remedy the trouble arising from the breakage of crank-axles, the machinery was made "outside-connected," the same as in an ordinary locomotive; and in order to obviate the defect found in attaching the machinery to the wooden car body, they designed and constructed a strong iron frame-

work, which should be entirely independent of the car body, and which should support the boiler and all the machinery.

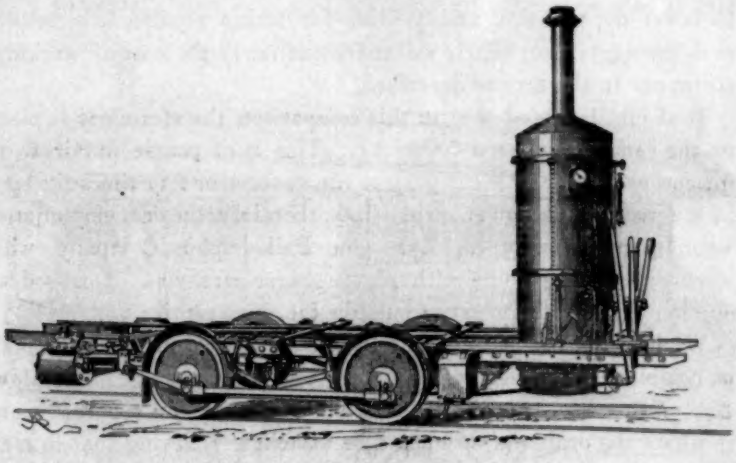
The car as thus reconstructed, was named the "Baldwin," and is shown by the following illustrations; one indicating the general appearance of the car in working order, and the other, the iron framework, carrying the boiler and machinery. This iron framework really constitutes a complete locomotive in itself, independent of the car body. It was finished and run by itself, without the car body being attached, on a trial at the Works. This design permits the use of existing cars, as the framework can be adapted to any car body. The cross-pieces shown in the cut support the body, which is held in position by three bolts on each side. Only the front



of the car where it adjoins the boiler needs any changing. The wheels are cast iron centres, fitted with steel tires, and are coupled by connecting rods on outside crank-pins. They are placed the same distance apart as the wheels of an ordinary horse car. The throttle valve is placed close to the cylinders, which gives the advantage of stopping and starting with great promptness. A powerful hand brake is provided, by which, with one motion of a lever, the engineer can stop the car in a few seconds. In addition to the brake, the engine can be reversed and back pressure used in case of emergency to arrest the motion almost instantaneously. The car is equalized on rubber springs with cross equalizing beams, and rides smoothly,

without any shaking or rough motion from the operation of its machinery. The boiler is of steel, double-riveted, and fully capable of carrying with safety a steam pressure of 300 pounds per square inch; only about 90 pounds pressure, however, is required to move it loaded over the heaviest grades on the Market Street line. It will thus be seen that every precaution in the interest of safety has been taken.

In conformity with an arrangement made with the President of the Company, the reconstructed steam-car "Baldwin" was placed on the Market Street line, March 21st, 1877, on the occasion of the trial trips made by the different steam-cars on that day. The maximum grades on this line are about four and one-half per cent., and up



these grades, and around the curves, in all weathers, and in all conditions of the track, the "Baldwin" has been run with entire facility, and without ever "stalling," or requiring assistance.

In order to determine the cost of the fuel, the coal consumed was weighed, as delivered to the car, for seven days. The aggregate quantity of fuel used was 4950 pounds for these seven days, during which the car made a mileage of 88 miles each day, or 616 miles in all. The average consumption of fuel was, therefore, 8·03 pounds of coal per mile run.

Four weeks' service of the "Baldwin" on the Market Street line terminated April 18th, and up to that date, the car had made 88 miles per day, and had run seven days in the week. It had never lost a trip, and at the date we speak of, occupied the same position on

the line as on the day it began service. It has required no repairs, except the ordinary care and attention from the engineers running it. The daily expense of running the car has been, therefore, as follows:

Total cost of fuel, per day, at 8 pounds per mile, 88 miles run, @ $4.00 per 2240 pounds, for anthracite coal, ...	$1.26
Oil, waste and tallow, per day, estimated, . .	0.25
Engineer, 16 hours per day, @ $0.25 per hour, .	4.00
Total cost, ...	$5.51

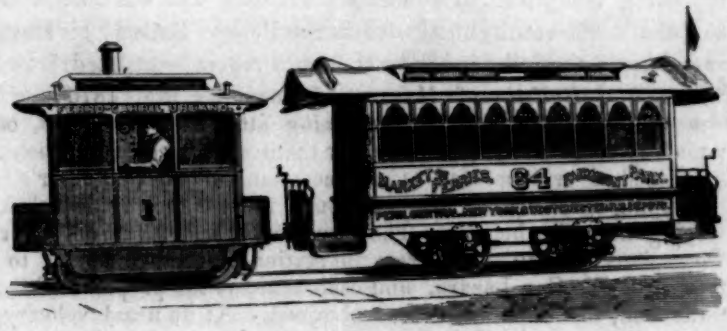
If to the above figures an allowance of one dollar per day is added, to cover depreciation and provide for future repairs, it is believed that the aggregate, $6.51, will represent fairly the cost of working a steam-car in the service described.

It should be noted that in this comparison the steam-car is placed on the same basis as a horse-car. This is of course unfair to the former, as it has ample capacity to run at three or four times the speed of a horse-car, and on suburban lines, therefore, the economy of steam would increase very rapidly. One Philadelphia Company, which works a suburban line with eleven horse-cars, has expressed the opinion that six steam-cars would do the same service.

We have thus far described only the steam-car, in which the boiler is combined with the car carrying the passengers. The Baldwin Locomotive Works early turned their attention to a separate motor, to which the ordinary cars could be attached, believing that in many cases economical and practical reasons would favor its use. The general principles involved in the separate motor are the same as in the steam car. Boiler and cylinders of equal capacity are used, and the machinery and wheels are all attached to an iron framework strongly braced. The entire weight of the boiler, machinery and water tanks, for a line with ordinary grades, is 12,000 pounds, which is no greater than the weight of a horse-car, when crowded with passengers. This is carried within the wheel-base, or the space between the two axles—thus doing away with all overhanging weight, front or back, and hence, with all rocking motion. The motor moves very steadily, and is, therefore, no more liable to damage the track than is an ordinary horse-car; in fact it is believed that by the steadiness of its motion, it is less damaging to the rails than a horse-

car. If steam is used in this manner, it will be seen that no changes whatever are required in the cars. The separate motor takes the place of two horses, and occupies the same space ahead of the car.

One of these motors was constructed in the fall of 1876, for the Citizens' Railway Company of Baltimore, the President of which line, Mr. John S. Hagerty, was quick to recognize the value and economy of this means of transit. The Citizens' Railway has maximum grades of seven feet per hundred, or $369\frac{6}{10}$ feet per mile. The service required by Mr. Hagerty, was that the motor should draw two loaded cars up this grade. The Baldwin Works constructed one machine, which was tried on the line, and was found fully capable of drawing one car, but with insufficient power for two. A second motor was accordingly built, which weighed about 16,000 pounds, and



which was sent to the Citizens' Railway in December, 1876, arriving there in the midst of the exceptionally severe snowstorms. During ten days' trial, it fully demonstrated its capacity to do the work required. It ascended the 369 feet grade, drawing one loaded car, when the tracks were covered with mixed snow and dirt to a depth of 8 to 10 inches in places. Where four horses were required to draw an ordinary car, the motor ascended the grade, drawing a loaded car without difficulty. As a result of this trial, the President of the company wrote on December 22d, as follows: "I have not tried it with two "cars, but it has had a test sufficient to guarantee us in taking it, so "far as climbing the hills is concerned. *It has gone up the grades "with one hundred passengers, on the worst day I have ever seen on*

"*our road.*" Subsequently the motor did its regular work and drew two cars without difficulty up the grade named. On several occasions, during the heavy snows of December and January, the motor was used to haul the sweeper for clearing the track, thus taking the place of from ten to fourteen horses, which were usually employed for the purpose. The city authorities of Baltimore, however, have not as yet granted permission for the regular use of this machine on that line, and it is therefore laid aside for the present.

Another and smaller motor, weighing only 12,000 pounds, was constructed about the same time for the Urbano Railway of Havana, Cuba. The illustration on the preceding page shows this machine. On its completion it was tried for some days on the Market Street line of this city, and drew one car regularly over the road, occasionally with as many as one hundred passengers. It worked with entire success, ascending the grades of 4½ feet per hundred, and was then shipped to Cuba. The results of its trial on the Urbano Railway of Havana, are given in the following extract from a report (translated) from the *Commercial Bulletin* of Havana, of November 9th, 1876: "The "machine which was to be tried, being attached to two cars, occu- "pied by some forty persons, drew them with a velocity which was "diminished or increased at the command of the conductor's bell, "stopping several times instantaneously without the slightest shaking "being noted in the cars. The experiment was made on different "occasions during the trip from the station of the 'Carmelo' to the "'Torreau de San Lazaro,' and each time, at the proper striking of "the bell, the same result was obtained. At its usual velocity, in "ascending a grade of two per cent. it can be stopped in three sec- "onds, and descending the same, in seven." It may be added that the consumption of fuel by this motor was found to be about the same as in the steam street car, viz.: eight pounds of coal per mile run.

Both of the motors above described were supplied with powerful steam brakes, by which the brakes could be applied instantaneously by opening a valve, admitting steam to the brake cylinder.

In conclusion, the following carefully prepared figures are presented, showing the economy of steam as compared with horse-power, for street railway traffic. Apart from the superior facilities afforded the traveling public by steam, the saving which can be effected, is, of course, the practical question involved. In the following table, the calculations are made on the basis of statements and reports of various street railway companies in Philadelphia:

Cost of Running one Two-horse Car one Day.

For one car 9 horses are required; first cost (at $140), $1260.

Feed and stable expenses (feed, straw, hostlers, stable boss and medicines) of 9 horses, at 46 cts.,	$4 14
Shoeing of 9 horses, at 6 cts.,	0 54
Maintenance of harness of 9 horses, at 2 cts.,	0 18
Maintenance of 9 horses (value $1260), at 33⅓ per cent. per annum for depreciation, equivalent per day for 9 horses to	1 15
Maintenance of car,	0 40
Wages of driver,	1 75
Daily interest on cost of car ($1000) and 9 horses ($1260), $2,260, at 6 per cent. per annum,	0 37
Total,	$8 53

In comparison with the above, the following statement of the cost of running a steam car is submitted. The figures in this case are taken from actual experience with the Baldwin steam car and motors on the Market Street line, in this city, as well as on other lines where these machines have been used. It is proper to state that the allowance for repairs and maintenance of the car and machinery is estimated. There has been no expenditure on the steam car on Market Street in over five weeks' service, under this head. Such slight repairs as have been necessary, in the way of keeping the machinery in adjustment, have been attended to by the engineers. Two engineers per day are employed, giving them ample time to attend to this matter:

Cost of Running one Steam Car one Day.

Fuel, 88 miles, at 8 pounds per mile, equal to 704 pounds, at $4 per 2240 pounds,	$1 26
Oil, waste and tallow,	0 25
Wages of engineers, 16 hours, at 25 cts. per hour,	4 00
Repairs and maintenance of car and machinery,	1 00
Daily interest on cost of steam car, $3000, at 6 per cent. per annum,	0 49
Total,	$7 00

Saving—steam over horse car, at $1.53 per day, equal to $558.45 per car per annum.

These figures, however, present only a partial view of the saving which may be effected. There are two elements of cost which are not

taken into account, viz.: the capacity of steam cars for greater speed, enabling a smaller number of cars to do the same service, and the saving in real estate and buildings requisite for stables, storage of feed, etc. In respect to the greater speed of steam cars, it should be remarked that this can be effected without increasing the rate of speed in the crowded streets of a city. Some saving of time can be effected even here, however, by the ability of the steam car to stop and start more quickly than a horse car; but a very great saving of time can be effected on the suburban parts of the line, by the possibility and desirability of a much higher speed than horse cars can attain. The following comparison is based on a road assumed to be worked by 50 cars and 450 horses. It will not be doubted but that the allowance of 40 steam cars to do the same service will be considered ample. It will also be admitted that one-fourth of the space will be sufficient to house the 40 steam cars, which would be required to house and stable 50 horse cars and 450 horses:

Annual Expenses of a Road worked by 50 *Cars and* 450 *Horses.*

Annual operating expenses, as above, .	$155,672 50
Interest on cost of real estate and buildings for car houses and stables (say $150,000), at 6 per cent., ...	9,000 00
Taxes, insurance on buildings and repairs of buildings, ...	3,000 00
Total, ...	$167,672 50

The same work could be done by 40 steam cars, at the following cost:

Annual operating expenses of 40 steam cars, as above, ...	$102,200 00
As stables may be dispensed with, and fewer cars require shelter, one-fourth the land and buildings would suffice. Interest on $37,500, cost of real estate and shed for steam cars, at 6 per cent., . .	2,250 00
Taxes, insurance on buildings and repairs of buildings, ...	750 00
Total, ...	$105,200 00

Annual saving, steam over horse cars, $62,472.50.

When these elements in the problem are taken into consideration, the saving which can be effected by a road worked as above, becomes enormous. In the above example it amounts to over thirty-seven and one quarter per cent. of the annual expenses for operating, taxes, insurances and repairs. It is believed that a much smaller proportion of steam cars, as compared with horse cars, than is assumed in above calculation, would suffice. On this point actual experience is requisite. It is certain, however, that the greatest economy and the most thorough solution of the problem will be reached by any company which abandons the old and commits itself fully to the new method of transit.

In this connection the following extract from the *Railroad Gazette* of September 22d, 1876, is given, having reference to the general principles connected with the use of steam for street railways, and especially to the separate motor above described:

"The problem of working steam on street roads has thus far been almost entirely in the hands of persons inexperienced in the construction of locomotive engines. It has been a very inviting field for immature engineers and scheming inventors, and they have pertinaciously clung to the idea of combining steam power with the vehicle for carrying passengers. This is open to a number of very grave objections. In the first place, the heat and the steam and smell from the boiler and machinery, being so very near to the passengers, is a very great annoyance; and secondly, if the engine gets out of order and must be laid up for repairs, the car must be laid up, too, and if the car gets out of order the engine must be laid up. The combination of the engine with the car also takes away much of the simplicity which may exist if the engine and car consist of two separate vehicles or units which can be coupled together or detached at will. An engine is also much more efficient if it can be employed to draw any car, and *vice versa* a car will perform more service if it can be coupled to any engine than if the two are inseparable.

"For these reasons many of those who have examined this subject carefully, and from a practical point of view, have concluded that the best kind of engine for street railroad service is the simplest possible form of locomotive, constructed so as to be entirely independent of the vehicle which carries the passengers.

"Quite recently we published an engraving of a French locomotive for street cars. This, it will be remembered, is a simple four-wheeled engine, inclosed by a very neat cab and coupled to an ordinary car.

"Since what may be called the Centennial discussion of the subject, the managers of the Baldwin Locomotive Works have given fresh

attention to the subject, and they have come to the conclusion stated above, that an engine independent of the car is very much better for this or any service, and they therefore designed and have just completed a locomotive for one of the Philadelphia roads in some respects similar to the French engine.

"These engines are, we believe, more promising of success than any other attempt in this direction has thus far been. They are in the hands of people who have some accurate knowledge of the effect of the law of gravitation on the operation of locomotives, and who can do more than guess at the steam-generating capacity of a boiler and of the proportions which one part of the machine should bear to another—information of which most of the schemers who have worked at this problem have been profoundly ignorant. Then, too, there is more hope of success if engines of this kind are built by good mechanics than if the workmanship on them is a sort of universal botch. We therefore expect to hear very soon of the successful use of steam power on street railroads, with a general expression of surprise on the part of everybody at the fact that it was never done before."

French Industrial Machinery.—The first steam engine was introduced into France in 1789. It was made by Boulton and Watt, of Birmingham, for the water-works of Paris. On account of the Revolution, and the consequent check of industrial enterprise, the manufacture of steam engines by French workmen did not assume much importance until 1824. The number of stationary engines had increased, in 1852, to 6000, representing 75,000 registered horse power; in 1863, to 22,500, representing 618,000 registered horse power; and now they represent 1,500,000 registered or 4,500,000 actual horse power, doing the work of 31,000,000 men, or of nearly ten times the available mechanical industrial population of the country.

In 1788, the cost of manual labor, in manufactured products, was 60 per cent., the raw material costing 40 per cent. Now, these proportions are reversed, the annual production being about 12,000,000,000 francs. Of this amount, 7,000,000,000 francs are paid for raw material, and 5,000,000,000 for labor. For the same amount of labor in 1788, an expenditure of 11,000,000,000 francs would have been required. There is therefore an annual saving of 6,000,000,000 francs, in consequence of the use of steam engines and improvements in machinery.—*Les Mondes* loc. cit.; from the *Journal Officiel.* C.

CERTAIN POINTS IN THE DEVELOPMENT AND PRACTICE OF MODERN AMERICAN LOCOMOTIVE ENGINEERING.

By Francis E. Galloupe, S. B.

[Continued from Vol. ciii, page 315.]

The resistance of the atmosphere also varies as the square of the speed. The train displaces a volume of air somewhat wider than the cars, which it carries along with it, and which causes an additional resistance by its friction against the surface of the ground.

The following are the directions and velocities of the wind during the three days on which data were taken, which I have obtained from the U. S. weather signal office in Boston.

Record of Wind.—Wednesday, March 15: general direction, W.; velocity, at 11·30 A. M., 36, at 12·35 P. M., 48 miles per hour.

Thursday, March 16: direction, veered to E., at 9·40 A. M.; velocity at 11 A. M., at Boston, 20 miles per hour. Thursday night at midnight, 30 miles per hour.

Friday, March 17: direction, wind continued E. till Friday noon; velocity, at 11 A. M., the maximum, 24 miles per hour, when the direction changed to N. E., and at 12·43 P. M., to N. W.

The formula employed by the U. S. signal service, by which to calculate the pressure of the wind from its velocity, is one used by Col. Henry James, R. E. F. R. S., and derived from a *Meteorological Paper of the British Board of Trade*,[1] in which the pressure per square foot, $P = v^2 \times \cdot 005$.

On this day the wind was almost dead against the train, and if we take its velocity at 36 miles per hour, the resistance due to this cause, calculated by this formula, was 6·48 lbs. per sq. ft., while that due to the velocity of the train itself, which was 30 miles, was 4·5 lbs. If we take the front exposed to this pressure at 13 feet in height and 9 in width we should have for the total atmospheric resistance, $10{\cdot}98 \times 117$ sq. ft. $= 1285$ lbs.

[1] Third No., page 99. See also a table calculated by same formula in Alex. Buchans' "Handy Book of Meteorology," and Loomis' "Meteorology."

The resistance of the atmosphere, wind, and of curves under one mile radius, are usually taken together and allowed for in the formula. Mr. Zerah Colburn, in "Locomotive Engineering," estimates that these increase the resistance one-half, or 50 per cent. Applying this correction to our resistance of 2296 lbs. previously found, we find for the total resistance, constantly overcome by this engine, reduced to the rail, 3444 lbs. If we add instead, our calculated atmospheric resistance, we get $2296 + 1285 = 3581$ lbs., which agrees pretty well with the above rule. But we have calculated that the tractive force, here, was 5671 lbs., and if we take the velocity of the wind at 48 miles per hour, instead of 36, we have the corresponding resistance, 1872 lbs., and the total resistance 4168 lbs., leaving 1503 lbs. unbalanced force for other resistances which must have existed as we have seen before, if the train was at a uniform velocity. This can be easily explained, for if the wind was ever so little upon one side of the train, a greatly increased area would be presented, upon which it would act.

The Efficiency of the Engine or Mechanism can now be found. The efficiency of the engine or mechanism

$$= \frac{\text{Useful work}}{\text{Useful work} + \text{the lost work}},$$

or, it is the ratio of the useful resistance overcome, to the total energy of the fluid on the piston. It is the product of the efficiencies of the pieces which transmit the power, and if the discussion of these parts of the engine had been taken up, it might be so found, by reducing the resistance overcome by each, to the driving point, or piston, by means of the principle of virtual velocities.

The formula for the efficiency of the mechanism as a whole, was originally proposed by the Count de Pambour, and is given by Rankine as follows:—

$$e = \frac{R_1\ (\text{Useful load})}{R\ (\text{Total resistance reduced to piston})}$$

$$= \frac{R_1}{(1+f)\,R_1 + R_0} = \frac{1}{1 + f + \frac{R_0}{R_1}}.$$

The total resistance R, consists of a constant part, R_0, which is the resistance unloaded, and a part increasing as the useful load, R_1. Now, the unloaded resistance, R_0, in the best engines, is, on an average, 1 lb. per square inch of piston,

or $R_0 = 1$ lb. $\times A \times 2 = 1 \times 201$ sq. in. $\times 2 = 402$ lbs. upon the two pistons. The value of the coefficient, f, the Count de Pambour takes at $\frac{1}{7} = \cdot 143$. Now, if we take the resistance overcome in moving the train at 30 miles an hour, as the useful load, or

$R_1 = T = \frac{4\,p\,A\,S}{\pi\,D} = 3444$ lbs. and reduce it to the piston, we obtain $2\,p\,A = \frac{R_1 \times \pi\,D}{2\,S} = \frac{3444 \times 16\,36}{4} = 11{,}585{\cdot}9$ lbs., and $\frac{R_0}{R_1} = \frac{2\,A}{2\,p\,A} = \frac{402}{11{,}585{\cdot}9} = \cdot 0347$. The efficiency of the mechanism is accordingly, $\frac{R_1}{R} = \frac{1}{1{\cdot}143 + \cdot 0347} = \cdot 85$ or 85^1 per cent. But this appears to be too high. From the speed and pressure given, the tractive power of 5671 lbs. which we found, must have balanced the resistances, and not have exceeded them, as the condition of uniform speed. Hence, if we take the resistance at 5671 lbs., at the circumference of the driving wheels, in the same manner as above, we find the effective pressure upon the pistons to be 23,194 lbs., the effective energy exerted per revolution, 92,778 ft. lbs., and the efficiency, 80 per cent.

But we may calculate it by yet another method. The tractive power exerted was 5671 lbs., the power consumed in overcoming the machinery friction, reduced to the rail, we have found to be 714 lbs. The efficiency of the mechanism is therefore, $\frac{5671 - 714}{5671}$, which gives 87 per cent.

In completing what I have had to say upon certain points in locomotive engineering, I have endeavored to present, not a finished essay upon the subject, but, perhaps, the less interesting results only, of the study and time devoted to it. Nothing has been said upon those important branches of locomotive engineering,—the permanent way, railway plant, watering stations, and shops, surveys and location of road, bed and ballasting, masonry, tunneling, the superstructure, rolling stock, or railway management. Nor upon the construction of locomotives in the workshop, and their draughting. Taking simply a single example of the finished product of our New England loco-

[1] From experiments by Mr. Wm. More and others, as stated by Rankine, the friction of the pistons alone was estimated at one-tenth the effective pressure, or 10 per cent.—"Mach. and Millwork," pp. 399 and 405.

motive establishments, I desired to apply to it some of the principles which we have been studying during our four years' course.

What I have been able to take up seems to me only suggestive. The subject is capable of indefinite development; it is inexhaustible.

To review, we have found the efficiency of the apparatus by which a portion of the energy in the coal is transferred to the working fluid; next the efficiency of this fluid has been ascertained; and finally, the efficiency of the mechanism, by which a portion of the energy utilized in the latter, has been finally given out as useful work, at the circumference of the wheels. The absolute efficiency of the locomotive is therefore the product of the three factors found, and is as follows:

1. Efficiency of Furnace and Boiler, . .	·557.
2. Efficiency of Steam, . . .	·071.
3. Efficiency of the Engine or Mechanism, .	·800.

Efficiency of the Locomotive engine, $\cdot 557 \times \cdot 071 \times \cdot 8 = \cdot 0316$, or *three and two-tenths per cent.* Of the power in the coal, *ninety-six and eight-tenths per cent.* is lost. Of the 10,316,236 foot pounds of work in each pound of coal, but 339,120 are utilized. For every ton of coal, costing $6.00 per ton, $19\frac{2}{10}$ cents are usefully invested, and $\$5.80\frac{8}{10}$, ineffectually applied. Of this, however, the greater portion, perhaps nearly 70 per cent.,[1] is lost by reason of natural conditions beyond our control.

The projects by which the locomotive engine is to be improved, by this remaining 20 or 30 per cent., relate to nearly all its parts. The boiler is an extremely wasteful piece of apparatus; its efficiency will be increased as the difference between the limits of temperature employed for the working fluid is greater, and hence when high pressures can be used, such as 200 or 400 lbs. to the square inch, and which depends in turn upon the introduction of seamless steel or welded boilers, or when means for condensation or for utilizing pressure below that of the atmosphere shall be rendered practicable, and when fuel shall have become more expensive, doubtless, eventually, other means will be employed for the production of power.

The defect in the use of steam seems to be radical. But a small proportion of the heat absorbed by it can be utilized. Although its use may sometime be abandoned, and the theoretic superiority of air,

[1] Art. "Losses of Power in the Steam Engine," *Scientific American*, Jan. 11, 1873.

as the absorbing and transmitting fluid can be easily shown,[1] and engines for its use have already been constructed, their complexity, and the other difficulties that stand in the way of their construction have as yet prevented them from exhibiting any superiority to the steam engine in its usual form.

In the mechanism it seems as if the limit of improvement had nearly been reached. The beauty and simplicity of the Stevenson link motion, the crank and its connections, leave nothing to be desired. The various forms of rotary engines have all disappeared before it. It is not to be doubted, however, that the action of the ordinary slide valves is imperfect, and here improvements, such as the "central exhaust," are from time to time being made.

The advantages or disadvantages of using superheated steam, or jacketing the cylinder with live steam, have been briefly considered in the part on steam.

Outside of these questions lies that of gauge. It has been affirmed that the expense of locomotive power and permanent way has been found to vary nearly as the gauge. In regard to this much disputed question, it has been my intention to work out further data, similar to those which have been given, for comparison, from one of the most successful of the narrow gauge roads—the Boston, Revere Beach and Lynn Railroad.

There can be good reasons given for altering nearly every detail for improvement in the locomotive engine, in directly opposite ways, and the excess of advantage of one over the other will determine in which direction the improvement shall lie.

To quote again from Professor Thurston, on this topic: "The direction of improvement has been marked by a continual increase of steam pressure, greater expansion, provision for obtaining dry steam, high piston speed," and "careful protection against loss of heat by conduction or radiation." To store the energy wasted by the brake, and to dispense with the present necessity of dragging a heavy tender weighing nineteen or twenty tons, would be steps in improvement relating to the locomotive as a whole. It would be to more effectually apply whatever power is already obtained in its final form.

There seems to be little inducement to perfect and economize in the operation of the locomotive at the present time, on account of

[1] Bourne's Treatise.

the indifference of those most concerned in regard to its practical efficiency. The value of making locomotive tests has, until now, been apparently little appreciated. Where the supply of motive power is unlimited, there is no practical value in a test whereby the possibility of a reduction in the amount of power required to do the same work may be indicated. If there was at Lowell more water power than could be possibly used, it is not likely that such care would have been bestowed and expense incurred, by the mill corporations, in accurately testing the water power and turbines there employed.

But with the locomotive engine, coal is not only a large item in the expense of railroads, but it also occupies space and consumes power in its transportation, and involves the expense of labor in applying it to its use. On railroads every shovelful, after it is landed in the coal sheds, is usually handled over from two to four times. Hence arises the practical value of tests by which the actual economy or wastefulness of the engine is indicated, and the direction in which to look for further economy and reduction in the necessary amount of coal pointed out.

Let us for a moment consider what should constitute such a test. A kind of test that has been at times employed for locomotives, has been to ascertain the number of cars, of known weight, that a given locomotive will haul up a certain grade or around a given curve, the speed being ascertained by noting the time occupied by the train in going a certain distance. But this really tells only the gross power of the engine, and does not inform us at all of how this power is distributed in the engine, what parts are efficiently working, and what not. A real test would be one carried on while the engine is doing its regular work, such as, for instance, carrying a train of a certain weight from Boston to Portsmouth and return. Let all the instruments of precision used for making tests—weighing scales, measuring scales, for the coal and water; a standard clock or watch for the time, a bell to indicate the time for the simultaneous taking of observations, the barometer, thermometers and pyrometers for the indication of temperature in the boiler, steam dome, steam pipes, steam chest, cylinders, tank, furnace and smoke box, the elegant recording steam gauge for the pressure, the friction brake, the dynamometer, the speed recorder or the counter, and the indicator—be employed, that are practicable in the limited space available by the construction of the locomotive. Let posts of observation for the

reading of these instruments be established at the points indicated—at the cylinders, in the cab, tender, and on the train—and complete logs kept of all the circumstances relating to the engine, without regard to their apparent irrelevancy to the subject, for it is owing to insufficient data that many records now obtained are rendered nearly valueless. And, finally, let the refined methods of physical science be applied to the data for the corrections; analyses made for the combustible matter in the coal, and especially the amount of moisture, the instruments re-tested, their errors ascertained and corrections applied.

From the data obtained at such a test, the details of which I might elaborate to a much greater extent, but the nature of which is sufficiently indicated in the outline above, when worked out and compared, we should obtain such a knowledge of the deficiencies in the locomotive as to show at once in what direction to look for further improvement and economy. It would place locomotive engineering upon a level with that of the other branches of mechanical engineering, and be of general scientific service besides. For it is only the exact facts that scientists and theorists require, in order to obtain a new insight into the working of the physical laws by which all our machines are governed, and produce results to which practice alone would never attain.

I cannot conclude with a more important observation than that of the real need of strict, accurate scientific tests. When such tests are made upon locomotives as that made in Jan., 1876, upon the pumping engine for the Providence Water Works, locomotive practice will not remain stationary, and locomotive engineering science will progress, ensuring results of practical benefit to all.

Cutting Cast Iron Tubes of Large Calibre.—An apparatus for this purpose, invented by Reishauer and Bluntschli, of Zurich, is described in the *Schweizerisches Gewerbeblatt* for 1876, p. 130. It is constructed of three cutting wheels, resting in stirrups which are pressed upon the tube by a connecting vice-screw. A cutting iron, between two of the cutting wheels, is pressed against the tube by a second screw, and the whole apparatus is turned around the tube by hand.—*Ding. Polyt. Jour.*, 223, 4. C.

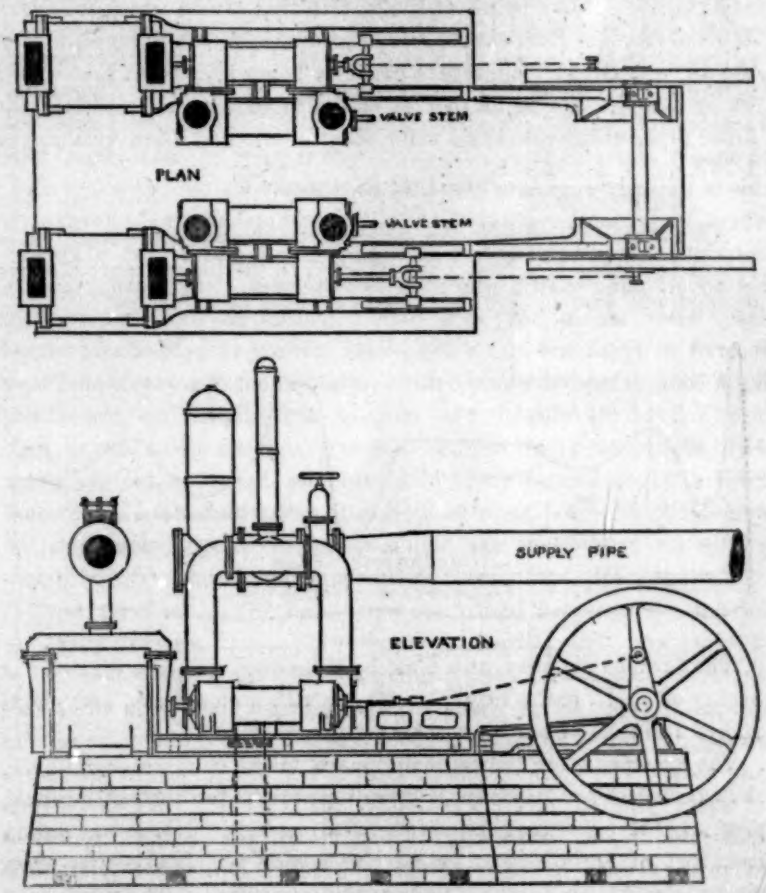
ROTATIVE WATER-PRESSURE ENGINE.

By Washington Jones, M.E.

The I. P. Morris Company, of this city, have constructed recently, at their Port Richmond Iron Works, a pair of water-pressure rotative engines, from the designs of Messrs. Taws and Hartman, mechanical engineers, and under the supervision of Mr. William Firmstone, President of the Longdale Iron Company, of Virginia; and intended to supply blast for that company's coke furnace at that place. As this is the only engine of the kind used in the United States, or elsewhere, so far as the writer is aware, to produce blast for a furnace, a description may be of interest. The general plan of the engine is not novel, being that in which the two cylinders for air and, in this case, water are in line, and, with a piston-rod common to both, secured at front end into a cross-head moving on guides, and carrying a connecting-rod whose outer end takes hold of a crank-pin fitted into hub of fly-wheel. The engines are coupled by one shaft, with cranks at right angles, and are mounted upon strong bed-girders, which extend from blast cylinder flange, under the water cylinder and beyond, so as to contain the shaft pedestals. The usual guides for cross-heads are bolted on top of these girders, and the whole is securely held down to a masonry foundation. The cylinders have the diameters of 18 ins. for water, and 48 ins. for blast, both of 5 ft. stroke. The pistons are fitted with double metallic rings, set out with springs. The water admission and discharge valves are of the piston type, 18 ins. diameter, and are also fitted with adjustable spring packing. Motion is given to them by the ordinary eccentrics and rods. The water is taken from a dam 65 ft. above the centre of water cylinders, and the available supply in dry seasons amounts to 4 cubic ft., but, ordinarily, to 6 cubic ft. per second. Sufficient of this quantity is conveyed by a riveted lap-jointed plate iron flume of 30 ins. diameter, and which is laid to conform with the general contour of the bank. From its point of attachment, to a wooden trunk of 5 ft. depth by 10 ft. width, it dips, at an angle of 20°, for 70 ft.; thence, by an easy bend, at an angle of 38° 30′, for 53 ft.; then changing, by another easy bend, into a horizontal line, it continues for 34 ft., when its diameter diminishes, in a length of 6 ft., to 24

ins., at which size it runs for 4 ft., and then branches right and left to the side pipes of water cylinders. The main pipe extends on for a short distance, and is then closed by joining an air vessel which is

WATER-PRESSURE ROTATIVE BLAST ENGINE OF THE LONGDALE IRON CO.

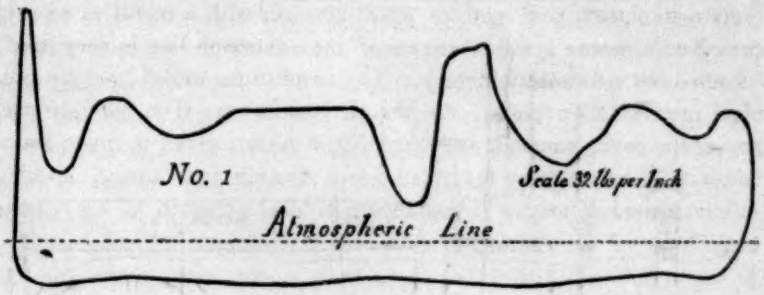


24 ins. diameter and 9 ft. high. Each of the branches is supplied with an air vessel of 10 ins. diameter and 9 ft. high. The exhaust water is discharged immediately downwards through a pipe 14½ ft. long, having its lower end, below the surface, in waste water way, which is 13 ft. below the centre of water cylinders.

The engines made, when first put up, 8½ double strokes per minute, but have been run up to 12 double strokes, without noise or shock. The blast pressure, when blowing into the furnace, was 3½ pounds; sometimes it fell as low as 3 pounds, but only at such times when the throttle-valve in water supply pipe was not fully open. Their steadiness of motion may be attributed to the large areas of water valves and chambers, they being equivalent to that of the water cylinders, and the freedom from shocks is due to the position and ample size of the air vessels, their aggregate capacity being over twice that of the water cylinders, or as 38 to 17½, and also to the large area of the flume pipe, which conveys a sufficiency of water at a low velocity, or

$$\frac{1{\cdot}767 \times 5 \times 2 \times 2 \times 8\frac{1}{2}}{4{\cdot}908 \times 60} = 1{\cdot}02 \text{ ft. per second.}$$

All the air carried into the cylinders by the water is permitted to escape by means of a bent pipe attached to the highest part of valve casings, and carried downwards into a vessel of water.

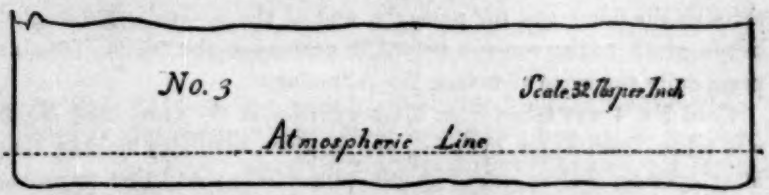


The furnace supplied with blast by these engines has a diameter at boshes of 11 ft. and a height of 60 ft., with a closed top, and yields 130 to 150 tons of hot blast coke pig per week.

The accompanying indicator diagrams, taken from water cylinder, show the effect produced by the use of air vessels on the water supply pipe, and of air escape pipes on valve casings. No. 1 was taken from forward end of water cylinder of engine No. 1, at a time when air vessels and air escape pipes were not in action. The number of revolutions were not noted, but they were evidently less than usual as the blast pressure was but 3 pounds per square inch. This was intended as a test to determine the efficiency of the air vessels. At the middle point of the admission line the sudden depression is evidently produced by the opening of valve on engine No. 2 to admit

water to its cylinder just when the piston of No. 1 had attained its greatest velocity, and the greatest supply was demanded; and, following it, an abrupt rise above the mean line due to the impulse of the accelerated motion and the sudden check of water column in supply pipes. This effect is twice repeated before the termination of the stroke, but in lessening degrees, and is caused, as stated, by the oscillations of the water column, and the presence of trapped air in valve casings. The action of engines was not even, and strong shocks

were produced: they were therefore stopped, and the two air vessels upon the valve chests put into use, but air escape pipes and cocks remained closed, and engines again started, with a result as seen in card No. 2, where the unevenness of the admission line is very much softened but still unsatisfactory. The revolutions were 7½ per minute, blast pressure 2¾ pounds. All the air vessels were then put into use, air escape cocks opened, and card No. 3 taken, which is quite satisfactory. The engines then had been running four hours, making 8½ revolutions kindly, and producing a blast pressure of 3½ pounds



per square inch. As circumstances required the location of engines to be at their present level of 13 ft. above surface of water in waste way, which diminished the head to that extent, the continuation of the exhaust water pipe below the water, utilizes the negative pressure due to the difference in levels. This will be seen on card No. 3, where the exhaust line falls below the atmospheric line 5·625 pounds.

The gross power of the water expended during one double stroke of the engines, assuming the capacity of the cylinders as the basis for determining its quantity, is equal to

$1{\cdot}767 \times 5 \times 2 \times 2 \times 78 \times 62{\cdot}4 = 172{,}007$ ft. pounds. When

running with the throttle wide open the blast pressure obtained was 4 pounds, corresponding to a power developed of $1809{\cdot}56 \times 5 \times 2 \times 2 \times 4 = 144{,}765$ ft. pounds. Consequently, the useful effect of machine is equal to $\frac{144765}{172007} = 84$ per centum.

As 4 pounds of blast are more than is required for the furnace, and as the supply of water is somewhat less than anticipated, the water cylinders were reduced recently by bushings to a diameter of $15\frac{3}{4}$ inches. The engines now run regularly at 12 revolutions per minute, and give a blast pressure of $2\frac{1}{8}$ pounds. The power developed is equal to $1{\cdot}353 \times 5 \times 2 \times 2 \times 78 \times 62{\cdot}4 = 131{,}702$ ft. pounds, and the work done in the blast cylinders is equal to $1809{\cdot}56 \times 5 \times 2 \times 2 \times 2\frac{1}{8} = 104{,}050$ ft. pounds. Consequently

the useful effect of the engines is now $= \frac{104050}{131702} = 79$ per centum.

The increased loss of effect, $84 - 79 = 5$ per centum, results from the reduction of capacity of water cylinders or a lessened power, whilst the prejudicial effect of friction of machines, of the water through the flume and the passages, and of the several right-angled bends given to the current before it acts upon the piston, remains practically the same as before the reduction.

Card No. 4 was taken from blast cylinder at the same time No. 3 was taken from water cylinder, and is given here only to show that blast cylinder valves are of ample proportions; and that no undue loss occurs in getting the air into or out of blast cylinders.

Before the adoption of this type of motor was decided on, it was considered by the proprietors, whether to build an overshot wheel, or to put in a turbine, or the proposed plan of the yet untried water pressure rotative engine. Objections existed against the use of the first two, as gearing had to be used to transmit the power to the work. It was therefore determined to try the engines just described, and their performance is so superior to any probable result from an overshot wheel or a turbine as to satisfy those concerned of the soundness of judgment evinced in their adoption.

ON THE PRODUCTION AND USE OF COMPRESSED AIR IN MINING OPERATIONS.[1]

By M. F. L. Cornet, Chief Engineer of the Mines of Eastern Flenu à Cuesmes, Cor. Member of the Scientific Section of the Royal Academy of Belgium.

[Translated from the French by Robert Zahner, Department of Engineering, Stevens Institute of Technology.] [ii]

Compressed Air.

§ 1. Of all means employed to drive the machinery of mines, compressed air is certainly that which is least objectionable, both on the scores of safety and convenience; but its application necessitates considerable expense in its first establishment, and the work which it yields, with the machines used at the present day, is only a small fraction of that which is expended in obtaining it at the surface.

[1] Considérations sur la Production et l'Emploi de l'Air Comprimé dans les travaux d'exploitation des mines, par M. F. L. Cornet, Ingénieur-Directeur des travaux des charbonnages du Levant du Flenu à Cuesmes, correspondant de la classe des Sciences de l'Académie Royale de Belgique. Deuxième édition. Mons, Hector Manceaux, imprimeur-éditeur. 1876.

[ii] Note.—The writer, some months ago, while studying the causes of loss of work in the use of compressed air—more particularly in its application to the actuation of rock drills and other mining machinery—was led to propose the more effective utilization of water in the absorption of the heat of compression, by injecting it in the condition of a very fine spray, as by the use of an atomizer, and under some peculiar conditions, in other respects, which need not be described here; and he soon after requested his colleague, Prof. De Volson Wood, to endeavor, by its experimental application, to determine whether the increased efficiency which seemed to be promised could be actually utilized. Meantime, the brochure of M. Cornet, of Mons, was received, and, finding it to contain a brief discussion of a plan resembling his own, so far as it went, the writer requested Mr. Zahner to translate it. It is here presented, as read before the classes of the Department of Engineering of the Stevens Institute of Technology, in the expectation that it may also interest some of the readers of the Journal.—R. H. Thurston.

Table of Factors.

1 metre = 39·37 inches = 3·28 feet.	1 "cheval à vapeur," or "force de cheval," = 75 kilogrammetres per sec. = 0·986 horse-power.
1 kilogramme = 2·205 pounds.	1 degree Cent. = $\frac{9}{5}$ degree. Fahr.
1 kilogrammetre = 7·23 foot pounds.	1 calorie = 3·968 Brit. thermal units.
1 cubic metre = 35·32 cubic feet.	
1 litre = 0·220 gallons.	

Nevertheless, air, like all permanent gases, has perfect elasticity, and, to be compressed to any tension, requires, theoretically, only a quantity of work strictly equal to that which it restores when returned to atmospheric pressure. Thus would it be in practice, allowance having been made for the losses attendant upon the use of all machines, if the compressed air were used immediately after leaving the compressor. But if, as is the case wherever this motor is employed, the air is relieved only after having been compressed for a considerable time, and in a machine situated at a great distance from the compressor, there occurs a physical change, which carries away a great part of the mechanical power which has been transmitted to it; if, during compression, the temperature of the air were to remain equal to that of the atmosphere from which it is drawn, the tension would increase according to Mariotte's law; that is to say, its pressure would, at every point in the course of the compressor-piston, be inversely proportional to the volume. But the work transmitted to the air is partly converted into heat, and the temperature increases with the tension. It follows from this that the tension increases more rapidly than is indicated by the law of Mariotte, and, consequently, the work necessary for compression is greater than it would be were the temperature of the air to remain constant.

Compression of Air.

Tension in Atmospheres.	Compression with Temperature const.		Compression with increase of Temperature.			Excess of the work due to heating the air.	Ratio between the quantities of the two preceding columns.
	Volume.	Work.	Temp.	Volume.	Work.		
Atm.	Cubic metre.	Kgm.	Degrees. C.	Cubic metre.	Kgm.		
1	1·000		20°	1·000			
2	0·500	7130	85·5°	0·612	7932	733	0·092
3	0·333	11856	130·4°	0·459	13360	2004	0·150
4	0·250	14260	165·6°	0·374	17737	3477	0·196
5	0·200	16580	195·3°	0·320	21209	4629	0·218
6	0·167	18475	220·5°	0·281	24310	5835	0·240
7	0·143	20038	243·2°	0.252	27048	7040	0·260
8	0 125	21422	263·6°	0·229	29518	8096	0·274

In order to give a complete exposition of the calorific effects which compression exercises upon air, we have prepared a table in which we furnish the results obtained by a calculation based on the

hypothesis that a cubic metre of air, taken at atmospheric pressure and at a temperature of 20° C., is given tensions of from one to eight atmospheres.[1]

We see, on examining this table, that with the compression following Mariotte's law, the volume of one cubic metre of atmospheric air is reduced to 0·125 cubic metre, when the tension reaches eight atmospheres; while if the compression is accompanied by an increase of temperature, and occurs without any loss of heat, the volume for the same tension measures 0·229 cubic metre. In raising the tension of the air from one to eight atmospheres, the temperature rises from 20° to 263·6° C., which produces this increase of volume after compression. In fact, for each elevation of 1° C., air possesses the property of expanding by a quantity equal to 0·00367 of the volume which it would occupy at the temperature of melting ice. We shall suppose now that, in escaping from the compressor, the air is introduced into a reservoir of very great capacity, where it remains sufficiently long for its temperature to become equal to that of the surrounding air; that is to say, equal to 20° C. If we then cause it to enter the cylinder of an expansion-engine, the phenomenon appears, to which we are about to refer.

Work at full pressure will be done without any sensible reduction of temperature, for the cylinder will remain, while doing this work, in communication with the reservoir, whose capacity we have assumed to be very great. But, beginning at the instant of cut-off, the work done by expansion will be at the expense of the heat which the air contains. The temperature will fall the more, the further expansion is carried, so that the decrease of tension in the cylinder will proceed in a much more rapid progression than that which the law of Mariotte gives. The quantity of work which the air yields will, therefore, be less than that which would have been obtained if the expansion could have proceeded according to this law.

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[1] The temperatures and volumes were calculated by means of the formulæ, $\frac{T}{T'} = \frac{P}{P'} \times \frac{291}{1000}$, and $V' = V \frac{P'}{P} \frac{T}{T'}$, in which T' is the absolute initial temperature (*i. e.*, $273 + 20 = 293°$; T = the absolute final temperature); P' the initial tension, or one atmosphere; P the tension to which the air is brought; V' the volume occupied by the air after compression; and V the volume before compression. In the case chosen V = one cubic metre. The quantities of work were determined by the aid of a polar planimeter on the diagrams which are annexed to this paper.

In the following table we compare the results which the law of Mariotte would furnish with those which could be obtained if two cubic metres of air, taken at atmospheric pressure, were caused to expand, having been given the tensions of five and eight atmospheres respectively, and restored, by cooling, to the temperature of 20° C.:

EXPANSION OF AIR.

INITIAL TENSION OF EIGHT ATMOSPHERES.					INITIAL TENSION OF FIVE ATMOSPHERES.				
	Mariotte's Law.		Exp'n with Cooling.			Mariotte's Law.		Exp'n with Cooling.	
Tensions in Atmospheres.	Temperature.	Volumes, cu. metres.	Temperature.	Volumes, cu. metres.	Tension in Atmospheres.	Temperature.	Volumes, cu. metres.	Temperature.	Volumes, cu. metres.
8	20°	0·125	+ 20·00	0·125					
7	20°	0 143	+ 8·80	0·137					
6	20°	0·167	— 3·50	0·153					
5	20°	0·200	— 17·40	0·174	5	20°	0·200	+ ·20°	0·200
4	20°	0·250	— 33·50	0·204	4	20°	0·250	+ 1·60°	0·234
3	20°	0·333	— 52·70	0·251	3	20°	0·333	— 20·40°	0·287
2	20°	0·500	— 77·20	0·334	2	20°	0·500	— 48·70°	0·383
1	20°	1·000	— 113·00	0·546	1	20°	1·000	— 89·50°	0·626
0·426	20°		— 148·20	1·000	0·526			— 120·80°	1·000

If expansion proceeds according to Mariotte's law, the tension will always be exactly restored to atmospheric pressure, when the volume of the air becomes equal to one cubic metre; *i. e.*, at the instant the piston has completed its course. But it is far from being so in the case in which the air undergoes considerable cooling while expanding. We see, on examining the table, that in the cylinder where the air was made to expand from a tension of eight atmospheres, atmospheric pressure is reached when the volume is only 0·546 cubic metre; that is, when the piston has traveled 0·546 cubic metre, its stroke being 1 metre, from this point the tension becomes less than that of the atmosphere, and it has descended to 0·426 atmosphere, when the volume reaches 1 metre—that is, when the piston has completed its stroke.

We have seen above, that in order to give 1 cubic metre of air, taken at atmospheric pressure and 20° C., a tension of 8 atmospheres, it is necessary to consume 29,518 kilogrammetres of work, if we allow the temperature to increase.

When this compressed air is restored within the reservoir to a temperature of 20° C., and is then made to expand cooling, it yields

16,146 kilogrammetres of work. But a part of this work, equal to 1657 kilogrammetres, is consumed in overcoming atmospheric pressure, so that the work actually realized is only 16146 — 1657 = 14489 kilogrammetres. The theoretically useful effect in this case is, therefore, only $\frac{14489}{29518} = 0{\cdot}490$.

If the tension of the air is 5 atmospheres, the consumption of work, in compression, amounts to 21,209 kilogrammetres. The work restored is 13,296 kilogrammetres; but 1085 kilogrammetres are spent in overcoming atmospheric pressure. Hence, 12,211 kilogrammetres remain free, and the useful effect amounts to $\frac{12211}{20209} = 0{\cdot}575$.

The loss of work is therefore less, with a tension of 5, than with one of 8 atmospheres. We may conclude that the useful effect decreases as the tension increases. This fact would be made more evident if calculations, similar to those whose results we have just given, were made for all tensions between 1 and 8 atmospheres.

The useful effects which we have just calculated for 8 and 5 atmospheres respectively, are theoretical, and could be obtained only with machines which would offer no passive resistance, no "dead spaces" (*espace nuisible*), and which could be put in communication with the compressor by pipes offering no resistance to the movement of the air. But we know that this is far from being the case in practice, and we think we ought to consider, as a minimum, a total loss equal to 30 per cent. of the motive power of which we dispose. Assuming this proportion we find, for the two cases we have chosen, that the useful work will be:

Tension eight atmospheres:— $\frac{14489 \times 70}{100} = 10{,}142$ k^m.

Useful effect: $\frac{10142}{29518} = 0{\cdot}343$.

Tension five atmospheres:— $\frac{12211 \times 70}{100} = 8548$ k^m.

Useful effect: $\frac{8548}{21209} = 0{\cdot}403$.

These useful effects are still greater than those obtained in practice, by reason of the occurrence, during expansion, of a phenomenon of which we have not yet spoken. Atmospheric air, even in the dryest seasons, always contains a certain quantity of water which maintains

itself in a state of vapor in the compressed air until expansion takes place in the cylinder. If the expansion be carried far enough, the temperature falls below the freezing point, and there is deposited in the ports of the cylinder a crust of ice which thickens rapidly and soon arrests the motion of the machine. This is why most of the compressed air machines produced up to date do not utilize expansion. Now, the quantity of work, which at full pressure any volume of compressed air can furnish, is very much below the sum total of the mechanical power which it possesses, as we may judge by the following figures, which represent the quantities of work which a cubic metre of atmospheric air, compressed to tensions of from two to eight atmospheres, can furnish by expansion and at full pressure:

Tensions. Atmos.	Work in Kilogrammetres.		Total Work.	Ratio between the Figures of Cols. 3 and 4.
	By Expansion.	At Full Pressure.		
1	2	3	4	
2	1963	5167	7130	0·725
3	4474	6882	11356	0·606
4	6510	7750	14260	0·543
5	8313	8267	16580	0·498
6	9867	8608	18475	0·466
7	11184	8854	20038	0·441
8	12380	9042	21422	0·422

We see by the above figures how important is the loss of work if air is used at full pressure only. The loss is greater as the tension is higher. Also, if we do not work expansively, the air must, for the sake of useful effect, be under the least possible tension.

We have calculated also above, the quantities of work which could be obtained from compressed air by carrying the expansion to its extreme limits. These, although very small relatively to the work consumed, are, nevertheless, larger than the work realized by employing air at full pressure only. We have, indeed, for the two cases chosen, the following results:—

Tension of eight atmospheres:—

Work consumed, . . . 29,518 k^m.

" realized, $\frac{9042 \times 70}{100} =$. 6329 k^m.

Useful effect, $\frac{6329}{29518} =$ . . . 0·214.

Tension of five atmospheres:—

Work consumed, . . . 21,209 k^m.

" realized, $\frac{8267 \times 70}{100} =$. 5787 k^m.

Useful effect, $\frac{5787}{21209} =$ . . 0·273.

In conclusion of this part of our work, we shall say then, that, if we employ no means for preventing a rise of temperature in the air during compression, or a fall during expansion, we shall secure in useful work only a small fraction of the power consumed. For a tension of five atmospheres, or four atmospheres over and above atmospheric pressure, which is that pretty generally used, the work usefully restored exceeds but little, a quarter of that which has been expended in compressing the air.

§ 2. We shall now enter upon the second part of our work, in which we intend to treat of the methods to be employed in order to derive from the use of compressed air a greater useful effect than that secured at present. These methods consist in the following:—

(1) To bring about in the compressor the cooling which the air now undergoes after having left it.

(2) To provide the expanding air with a quantity of heat sufficient to keep its temperature constant, or at least to keep it from descending so low as to produce ice.

The compressors now in use belong to two principal classes. In the one, the compression is effected in the presence of water, while in the other it is done with the air in the dry state, water being applied only to the exterior of the machine to cool its walls.

Where cooling is the object, compressors of the first of the above classes seem to present greater advantages than those of the second, since the air is here in direct contact with the water; while in machines which compress the air dry, the air is separated from the water by thick cast-iron walls. Meanwhile, the results derived from experiment prove that, compressed in the presence of water, air undergoes but a slight cooling. Fig. 1 represents a diagram taken from the air compressor used in the Marie colliery at

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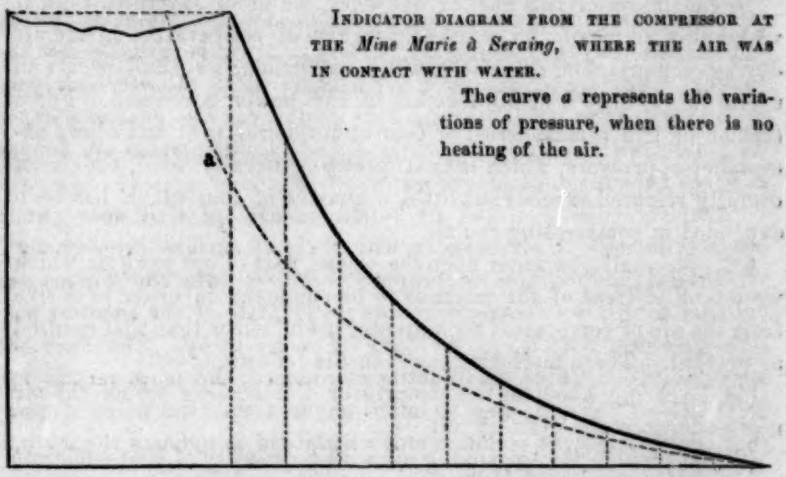
[1] *Compressed-Air Drilling Machines*, applied to mining operations, by M. A. Daxhelet. Annual of the Society of Engineers of L'École de Liége, Vol. XV.

Seraing[1]. The stroke of the compressor piston is 1·2 metres and its diameter is ·45 metre. The mean pressure per square metre, calculated from the diagram, was 19,962 kilogrammes, corresponding to 3809 kilogrammetres of work. The dotted curve in the diagram is the one which would have been traced had the compression followed Mariotte's law; that is, had the air not been heated during the compression. It corresponds to a mean pressure per square metre of 16,588 kilogrammes and 3164 kilogrammetres of work. The ratio of the work really expended to that which would have been, had the temperature remained constant, is expressed by the fraction $\frac{3164}{3809} = 0{\cdot}830$. Had there been no cooling of the air, the ratio of these two quantities, according to the figures given in our first table, would have been expressed by $\frac{16580}{21209} = 0{\cdot}78$.

Fig. 1.



INDICATOR DIAGRAM FROM THE COMPRESSOR AT THE *Mine Marie à Seraing*, WHERE THE AIR WAS IN CONTACT WITH WATER.

The curve *a* represents the variations of pressure, when there is no heating of the air.

Calculation shows that the temperature was 147° C. at the end of the stroke during which the diagram was taken; while it would have risen 195·3° had there been no loss of heat. In this calculation, we have supposed the temperature of the atmosphere to be 20° C. Machines for compressing in the presence of water, when this liquid is applied as in the machines at Seraing, therefore present but very little advantage on the score of cooling the air. Their inefficiency

ought, we think, to be attributed principally to the following fact, known ever since the experiments of Rumford, namely: that water possesses, in a slight degree only, the property of conducting through its mass, heat received on its upper surface. In the machine at Seraing, the air at the time of compression, rests on the water. The surface of the water is indeed heated, and from an increase of the temperature of the surface there results a decrease in its density, which makes it impossible for the thin superficial sheet of water at the top to be replaced by the colder water underneath. It is probable that the cooling, relatively of but little importance, which the air undergoes in the compressor at the Marie mine, is due, for the greater part, to its contact with the cast-iron walls of the cylinder, which are flooded at every return stroke of the piston.

Complete cooling of the air would be effected if it were put in contact during its compression with a liquid surface large enough. To obtain this surface we propose to inject into the compressor cylinder a certain quantity of water in the state of the smallest possible globules, that is, in the form of *water-spray*. The finer the spray and the greater the quantity introduced, the more certain will be the effect, but as it may be important in a practical point of view, that this quantity be a minimum, we proceed to indicate the method to be pursued in calculating it.

We accept as demonstrated the following facts:

(1) The quantity of heat contained in any volume of air, is proportional to its weight and temperature, and has no relation whatever to the tension.

(2) A cubic metre of air at the temperature of melting ice, and at the pressure of an atmosphere, taken equal to a column of mercury of 0·76 metre, weighs 1·293 kilogrammes.

(3) When a definite volume of air, whose tension remains constant, is caused to expand by the application of heat, the increase in volume which results is, for each degree C., the $\frac{1}{273}$ of the volume which the gas would occupy at zero. In this case the quantity of heat required is equal to the 0·2374 of that which would raise to the same temperature a weight of water equal to that of the air.

(4) When the air is maintained under constant volume, to produce a given increase in its temperature, a quantity of heat is necessary

equal to the 0·168 of that which would be needed to effect the same increase of temperature in an equal weight of water.[1]

(5) A thermal unit (*calorie*), that is, the quantity of heat necessary to raise 1 kilogramme of water, at zero, through 1° C., represents the quantity of heat necessary to yield 424 kilogrammetres of work.

We have seen above that a cubic metre of air, taken at atmospheric pressure, and the temperature of 20° C., requires, in order to be compressed to eight atmospheres and introduced into the reservoir, 21,422 kilogrammetres of work, assuming that its temperature remains constant; *i. e.*, that the tension during the compression follows Mariotte's law.

This, theoretically, is the quantity of work expended by the steam engine performing the compression; but it is less than the work actually necessary, for atmospheric pressure comes to the aid of the steam and furnishes 10,334 kilogrammetres of work; so that a cubic metre of atmospheric air, compressed and in the reservoir, represents the work of $21422 + 10334 = 31756$ kilogrammetres. This work is made up of two parts:

(1) The quantity expended in bringing the air from atmospheric pressure, to that (the pressure) of the reservoir.

(2) The work necessary to force the air into the reservoir.

This last quantity is equal to VP; V being the volume occupied by the air at the moment when its tension equals that of the air in the reservoir. In case the latter be eight atmospheres, the work expended to force the air out of the cylinder is:

$$10334 \times 8 \times 0{\cdot}125 \text{ m.} = 10334 \text{ k}^{\text{m}}.$$

The work necessary to bring the air to the tension of the reservoir is, therefore:

$$31756 - 10334 = 21422 \text{ k}^{\text{m}}.$$

When the air is taken from the atmosphere, its temperature is 20° C. Since we assume that the compression is to follow Mariotte's law, it will still possess this temperature when its tension has attained that of the air in the reservoir; *i. e.*, when its volume is reduced to 0·125 cubic metre. The air has, therefore, neither gained nor lost in

[1] Physicists are not quite agreed as to the value of the specific heat of air under constant volume. But even an important difference between the real coefficient and that of 0·168, here assumed, would affect only very slightly the results of the calculations, as we find further on.

heat, but we have expended upon it, in order to compress it, 21,422 kilogrammetres of work. Now as no work can disappear without the production of heat, we must admit that, to keep the temperature constant during compression, it is necessary that $\frac{21422}{424} = 50{\cdot}52$ thermal units be absorbed.

It is doubtful whether we can, in practice, by the aid of water-spray, exactly maintain the temperature of the air at 20° C., chiefly on account of the slight difference ordinarily existing between the temperature of the surrounding air and that of the water used for cooling. We believe that it is agreed that the temperature of the air during compression is higher by a certain quantity than that of the atmosphere.

If we suppose, for example, that with water at 15° C. we cannot lower the temperature below 39° C., the compression will not at first follow Mariotte's law, but only from the moment when it has attained the temperature which coincides exactly with a tension of 1·25 atmospheres. The compression to eight atmospheres, of a cubic metre of air under these conditions, calls for 22,711 kilogrammetres of work, equivalent to $\frac{22711}{424} = 53{\cdot}56$ thermal units; but a part of this heat is employed in raising the temperature from 20° to 39° C.

It is equal to $1{\cdot}199 \times 0{\cdot}168\ (39 - 20) = 3{\cdot}83$ thermal units, 1·199 being the weight in kilogrammes of a cubic metre of air at atmospheric pressure and 20° C., so that the heat to be absorbed amounts to $53\ 56 - 3{\cdot}83 = 49{\cdot}73$ metric thermal units. Each kilogramme of water which we introduce into the compressor at 15° C., absorbs $39 - 15 = 24$ thermal units. It is therefore necessary to use $\frac{49{\cdot}53}{24} = 2\ 062$ k^{s}. of water.

(To be continued.)

New Alloy of Iron.—Sideraphthite is composed of 66 parts of iron, 23 of nickel, 4 of tungsten, 5 of aluminum, 5 of copper. It is not attacked by sulphureted hydrogen, or by vegetable acids, and is only slightly corroded by mineral acids. It is more useful than silver, and may be prepared at less expense than German silver. It seems likely to supplant many of the alloys which require plating to prevent oxidation.—*Les Mondes*, April 12. C.

Chemistry, Physics, Technology, etc.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[i]

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. ciii, page 334.]

Utilization of Burnt Ores.—In the French department of the Vienna Exhibition the chemical works of the company St. Gobain, Chauny and Cirey, displayed iron obtained from non-cupriferous burnt pyrites. The thorough roasting of the pyrites, which makes it capable of being worked for iron, is said to have been effected by allowing the smalls to cool in thin layers, and roasting them repeatedly in Perret's furnace. The burning was effected by charging the plates alternately with burnt and with green ore. The hot gases evolved from the green smalls play over the plates charged with burnt ore and effect a second roasting.

In 1859, List pointed out the existence of zinc in the iron pyrites of the "Sicilia" mine.[ii] P. W. Hofmann ascertained that this zinc is present in the burnt ore in the state of sulphate, and extracted it by systematic lixiviation.[iii] The solution thus obtained, sp. gr. 1·25, consists almost entirely of sulphate of zinc along with a little copperas. It is heated to about 40° and mixed with common salt in equivalent quantity. Thus there is produced a solution of sp. gr. 1·38, which, on cooling, deposits sulphate of soda in sufficient quantity to cover all expenses. The mother-liquid is concentrated to 1·60 sp. gr., and the chloride of zinc thus obtained, containing mere traces of sulphates and of iron, is sold either in the liquid or the solid form. According to P. W. Hofmann's account large quantities of zinc chloride are thus obtained at Wocklum, from the sulphur ores of the "Sicilia."

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[i] "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

[ii] List, *Tech. Chem. Mittheilungen*. Hague, 1859.

[iii] P. W. Hofmann, private communication.

Richters[i] shows to what extent and under what circumstances the smelting of ores so rich in sulphur as are burnt pyrites in Germany, could, from a chemical point of view, prove successful. In fact, many attempts have been made to utilize the burnt ores for the production of crude iron, but none of the methods proposed have found acceptance. In England the burnt Spanish, Portuguese and some of the Norwegian pyrites are used after roasting. Wedding and Ulrich have carefully studied and described the treatment of burnt ores in England.[ii]

The burnt ore is sold by the chemical works to copper smelters with an average percentage of 3·66 sulphur, 58·25 iron, and 4·14 copper. It is first ground, then mixed with 15 to 20 per cent. of salt, and submitted to a chlorinized roasting in reverberatories or muffle furnaces. The gases evolved are condensed in a coke tower through which water flows, thus furnishing a mixture of hydrochloric and sulphuric acid. The copper is converted by roasting into a soluble chloride, which is extracted first with water and then with the acid mixture from the condensation tower. The copper is then precipitated by iron. After nine successive lixiviations the residue contains merely from 0·08 to 0·2 per cent. of copper, and 0·16 to 0·25 of sulphur, and is smelted for iron in blast furnaces as "purple-ore." A part is also used in lining the puddling furnaces, and another small portion is reduced with coal to the state of spongy iron, and then serves to precipitate metallic copper from its solutions.

Claudet[iii] patented a process in England for recovering the silver which is dissolved in the saline liquors as silver chloride by precipitation with iodide of potassium. His process is even applicable to ores containing merely 0·027 per cent. of silver. The liquors formed by extracting the roasted ores with water contains 95 per cent. of all the silver present; from these liquors the silver is precipitated to the extent of about 11·6 grms. per ton of ore. The net profit amounts to two shillings per ton of ore, giving at the Widnes copper works a yearly return of £3000.

When coal in Lancashire cost 5s. per ton, Phillips,[iv] after extracting the copper, precipitated the iron, and obtained fine sulphate of soda

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[i] Richters, *Dingler*, excix, 292.

[ii] Wedding and Ulrich, *Zeitsch. Berg. Hutten. u. Salinen w.*, xix, 292.

[iii] Claudet, *Chem. News*, 1871, 184.

[iv] Private communication.

by evaporating the mother-liquor. At the present price of coal this process has been abandoned.

The chemical works of Aussig and Griesheim exhibited at Vienna large quantities of thallium. This metal is obtained from the flue dust formed on burning pyrites, deposited between the kilns and the chambers. Max Schaffner[1] describes the process employed at Aussig. The flue dust is repeatedly boiled in water acidulated with sulphuric acid, and from the filtered solution the metal is precipitated on the addition of hydrochloric acid as impure thallous chloride. The precipitate is washed with cold water and converted into sulphate by heating with concentrated sulphuric acid. The sulphate is then dissolved in water and again mixed with hydrochloric acid, which precipitates tolerably pure thallous chloride. This is again treated with sulphuric acid, and the sulphate is reduced with pure metallic zinc. The metallic sponge thus obtained is washed with well-boiled water, dried between blotting paper, and melted over the lamp in a porcelain crucible, into which a stream of coal-gas or of hydrogen is conducted.

Roasting of Various Metallic Sulphides.—At Freiberg and in the Harz, galena is used for the manufacture of sulphuric acid, and is roasted for this purpose in large wide shaft-furnaces containing 250 cwts. The ore gives off the half of its sulphur and yields a gaseous mixture containing 4 to 6 per cent. of sulphurous acid.

Copper pyrites are used for making sulphuric acid both at Chessy and at Oker in the Harz, and are roasted for this purpose in small tubes. At Mansfield also copper ores are desulphurized in kilns, the Gerstenhöfer furnaces introduced for this purpose having been abandoned. In Swansea, on the other hand, the ground ore is roasted in Gerstenhöfer furnaces, which are there found to work satisfactorily. The lead chambers at Swansea are at the distance of about 20 metres from the furnaces, so that the greater part of the flue dust is deposited before reaching the chambers.

In the "Report on the London Exhibition of 1862," Dr. A. W. Hofmann[2] mentions that Lawes, of Barking Creek, on the Thames, employs in the manufacture of sulphuric acid the oxide of iron which has served for the purification of coal-gas, and which has become rich

[1] Schaffner, *Sitzb. d. k. Akad. d. Wissenschaft.*, 53, Feb.; *Wagner Jahresber.*, 1871, 1.

[2] A. W. Hofmann, "Report by the Juries," 1862, 15.

in sulphur. This so-called "Laming's mass" is now also used by the St. Gobain Company, of Aubervilliers, near Paris; by Seybel, of Liesing, near Vienna; by Kunheim and Co., of Berlin, and probably also elsewhere. The roasting is conducted partly upon earthen plates, partly in furnaces with narrow grates, the gases obtained being well suited for the manufacture of sulphuric acid.

Zinc blende has found of late years a more extended employment in the manufacture of sulphuric acid, and its use will probably be further extended. The chemical works "Rhenania," at Stolberg, near Aachen, may claim the merit of having thoroughly studied the utilization of the gases escaping on roasting zinc blende, and of having carried the process out in the most complete manner. Twenty years ago blende was roasted at Stolberg in a reverberatory furnace of two stages, according to F. W. Hasenclever's patent. The upper hearth formed a muffle constructed of vaults, in which the blende underwent a preliminary roasting, the sulphurous acid evolved being passed into the chambers. The roasting of the ore was then completed on the lower hearth. When pyrites were cheap it was not remunerative to use blende, as the desulphurization remained imperfect and gases too poor in sulphurous acid entered the chambers. The simple muffle-furnace was improved by Eugene Godin, whose plan did not come into operation at Stolberg until 1865, after his death. The ores, before arriving upon the hearth of the reverberatory heated by the products of combustion, pass over seven plates of fire-clay, arranged one above another. The spent ores are withdrawn below, the charge of the second is removed to the first, and that of the third to the second, etc., and green ore is thrown upon the seventh. In this furnace the roasting took place in a satisfactory manner, and the gases were rich in sulphurous acid. Labor, however, was high, and the loss of gas whilst charging was considerable. If the draft was increased the gases were too much diluted by the entrance of air at the doors.

In 1866 the Gerstenhöfer furnace was introduced at Stolberg for roasting zinc blende and used for some time. At the best it only succeeded in utilizing half the sulphur of the blende. On the other hand, the amount of flue dust (the blende there in use being very finely granular) was excessive, so that this furnace has proved as little adapted for roasting blende at Stolberg as at Borbeck and Swansea.

(To be continued.)

THE FLOW OF SOLIDS.

By Lewis S. Ware, C. E.

It is a comparatively recent discovery that solids as well as liquids are possessed of fluidity under favoring circumstances, but the investigations in this direction have not been numerous. Much attention was given to this subject by M. Tresca of the Conservatoire des Arts et Métiers in Paris. Having witnessed some of his experiments and seen the results of others, I have thought a statement of them would be of interest to the general reader and of value to workers in metal, who, though most frequently using solids not in this condition, yet very often having to deal with this flow, it is highly important that they should know the laws which govern it. These laws are but little known, and for that reason the experiments of M. Tresca, will help to fill a space up to the present time greatly neglected. Those who visited the Centennial Exhibition saw various machines used in piercing iron, even in plates several inches thick, apparently with great ease. I have thought it well to divide the subject into two parts.

Part I.—*Practical Experiments.*

If a cylinder of lead, three inches long, be placed between two iron plates, having each a hole ¾ of an inch in diameter, the holes opposite each other; if we cause a punch to pass through first hole (plate 1) penetrating the cylinder of lead, causing the expelled portion *L* to pass through the second hole in plate 2; the portion expelled will be found to have for its dimensions ¾ of an inch in diameter and one inch in height, instead of three, as should have been if the derangement of the matter had taken place in the direction of the movement.

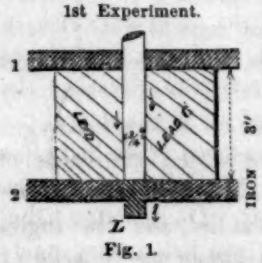


Fig. 1.

This phenomenon could be explained by supposing a different density, for the compressed portion; upon examination this hypothesis

is found to be erroneous, and M. Tresca was the first to discover the true reason. His experiment (Fig. 2) consisted in placing, instead of a leaden cylinder *C*, a series of plates of the same metal.

M. Tresca's 1st Experiment.

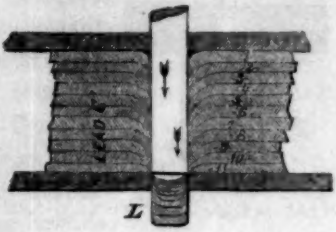


Fig. 2.

The punching was again begun, the portion expelled (*L*) is composed of unequal layers, each of which represents the plates (1, 2, 3, etc.). Those of the upper portion, except the first are extremely thin and hardly visible to the eye.

We can conclude from this, that portions coming in contact with the punch, were forced back into the layers of lead. This gave the first hints of internal movements that may take place from pressure on solid masses.

2d Experiment.

Fig. 3.

Flowing of the cylinder C *through a concentric orifice* (Fig. 3).

This experiment is very much the same as those we have just examined, a piston taking the place of the punch; pressure being applied, the lead escapes through a circular orifice, having the same centre as the axis of *C*. We have here a jet, the shape of which is a cylinder, enabling us to obtain information in regard to the internal changes taking place in *C*.

Remark.—If the orifice in the last experiment had been a polygon instead of a circle, we should have obtained a jet, the shape of which would have been that of a polygon, having the same number of sides as the orifice; these sides become smaller, and the angles more rounded, as we approach the centre, where they are replaced by an almost perfect circle. Here is a phenomenon exactly the same as the one observed by M. Bazin, in his researches on the transverse sections of flowing liquids.

When the height of the cylinder *C* (Fig. 4) is less than the radius of the orifice, there is an internal cavity in the jet, the shape of which is extremely regular, so much so, that it can easily be expressed by an equation. If we observe what takes place when the pressure becomes still greater, it will be seen that the external appearance of the jet (Fig. 5) is the same as that of a liquid (contraction of the vein). This is the only experiment that "M. Tresca" showed me in which this phenomenon was visible.

3d Experiment.

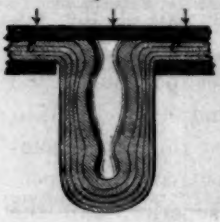


Fig. 4.

The next two show more and more the great similarity existing between the laws of flow of liquids and solids.

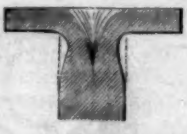


Fig. 5.

They differ from those we have examined, in the shape given to the metal before being submitted to a pressure. Instead of plates placed one on the other, they are *concentric cylinders*. If a section through the axis of the entire mass be examined after the pressure has had its effect, it will be seen that all the molecules composing *C* have a tendency to move in the direction of the orifice, after which they move parallel with each other.

4th Experiment.

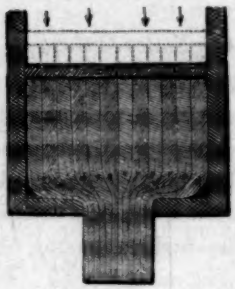


Fig. 6.

Remark.—It is a well known fact, that all calculations concerning liquids, are based on the hypothesis of parallelism of the molecules in movement.

The external appearance of the vein (owing to the influence of the air friction, etc.), has a tendency to mislead the observer.

5th Experiment.

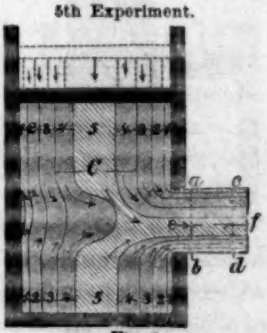


Fig. 7.

Flowing of C *through a lateral orifice.*

When the pressure is exerted on the upper part of *C*, it is transmitted to the interior of the mass, causing a jet to form, having a cylin-

Vertical section of jet.
Section A B.

Fig. 8.

Fig. 9.

Section C D.

drical shape, offering many interesting peculiarities. If sections be made perpendicular to the axis of the jet, it will be seen that (1), (2), (3), etc., form each a distinct portion of the total. If Figs. 8 and 9 be examined it will be found that this jet is composed of two distinct parts, one corresponding to the superior, and the other to the inferior portion of *C*.

The existence of the above can be better realized if a section perpendicular to the orifice be made (see Fig. 10).

Section E F.

Fig. 10.

All this movement takes place with great regularity, as shown by Figs. 8, 9, and 10.

Part II.—*Theoretical Calculations.*

I will now endeavor to show what takes place during the period of pressure; the argument will be based on two hypotheses, after which I will give an experiment, also made by M. Tresca, expressly for the purpose of determining how near these theoretical calculations are to the actual fact.

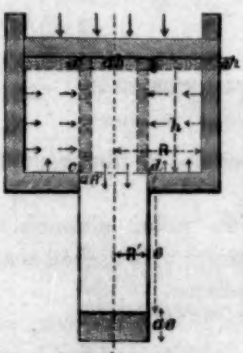


Fig. 11.

I have already stated, that the volume of the jet, added to that of the cylinder, forms a quantity that is constant before and after the pressure. In other words, a decrease of *C* will correspond to an increase of the jet, the density through the entire mass remaining the same, if we suppose that *R* is the radius of *C*, and *R'* radius of orifice, *h* height of *C* at any moment during the pressure, *H* height of *C* before pressure, *l* length of jet corresponding to a pressure $(H - h)$.

If we suppose a small decrease $(-dh)$ in the height of *h*, corresponding to an increase (dl) in the jet, these volumes being the same, we have:

$$-\pi R^2 d h = \pi R'^2 d l, \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

hence,

$$d h = -\frac{R'^2 d l}{R^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The equation (1) is necessary in our future calculations.

First Hypothesis.—Concentric contraction of the central cylinder (*a b c d*), having a radius $R' =$ to the radius of the jet.

If we admit the existence of a central cylinder, we shall have a ring which is the remaining portion of *C*, having R' for its interior, and R for its exterior radius.

If a pressure be exerted on the upper part of *C*, at every decrease of $h = d h$, the matter composing the ring, not being able to make its escape either in the direction of the pressure, or through the sides (the latter being sufficiently strong to resist it), will have its effect on the central cylinder *a b c d*.

The pressure on all sides being the same, we will not be far from the truth in saying that this *central cylinder* is transformed into a new surface of revolution, having the same axis as before. The most simple of all, is to suppose that it is still a cylinder. In this hypothesis it must be admitted that a decrease of the volume of the ring, when its height is diminished $-d h$, is compensated by a corresponding increase resulting from the decrease of R' of a quantity $= d R'$.

$$\pi (R^2 - R'^2) d h = 2 \pi R' d R' h,$$
$$(R^2 - R'^2) d h = 2 R' d R' h.$$

Hence,

$$\frac{d h}{h} = \frac{2 R' d R'}{R^2 - R'^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Second Hypothesis.—Proportional contraction of the central cylinder.

This central cylinder, *a b c d*, cannot have its radius diminished unless certain movements take place in the interior of a second *central cylinder* concentric to the first, having a radius *r*.

All actions being exerted in an equal manner around its axis, we can admit that this cylinder, having a radius *r*, will be modified in its transverse section proportionally to the one it primarily had. Hence,

$$\frac{d (\pi r^2)}{\pi r^2} = \frac{d (\pi R'^2)}{\pi R'^2} \text{ or } \frac{d r}{r} = \frac{d R'}{R'}. \quad . \quad . \quad . \quad . \quad (3)$$

Equation of the locus described by any given point of the convex surface of the central cylinder, having a radius R' :

To obtain this equation, it will be necessary to eliminate h, $d\,h$, $d\,R'$, between the equations (1), (2), (3). This is done in the following manner:

If we find the integral of (a), we have $R^2\,h = -R'^2\,l + C$, but when $h = H$, we have $l = o$; this gives $R^2\,H = C$. Hence,

$$h = \frac{R^2\,H - R'^2\,l}{R^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

If we divide (1) by (b), we will have,

$$\frac{d\,h}{h} = \frac{\frac{R^2\,d\,l}{R^2}}{\frac{R^2\,H - R'^2\,l}{R^2}} = -\frac{R'^2\,d\,l}{R^2\,H - R'^2\,l}. \quad . \quad . \quad . \quad (c)$$

If from (3) we obtain the value of $d\,R'$, and substitute this in (2), it will give,

$$\frac{d\,h}{h} = \frac{2\,R'^2}{R^2 - R'^2}\,\frac{d\,r}{r} = -\frac{R'^2\,d\,l}{R^2\,H - R'^2\,l}.$$

Hence, by integration, we have:

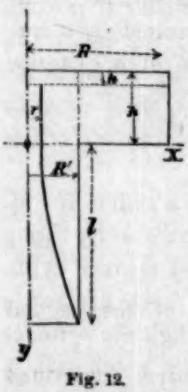


Fig. 12.

$$\text{Log}'\,r = \frac{R^2 - R'^2}{2\,R'^2}.\ \text{Log}'\,\frac{(R^2\,H - R'^2\,h)}{R^2\,H} + C, \quad (4)$$

but when $r = R'$, we have $l = o$; this gives,

$$\text{Log}'\,R' = \frac{R^2 - R'^2}{2\,R'^2}.\ \text{Log}'\,R^2\,H + C. \quad . \quad (5)$$

If we subtract (4) and (5), we have,

$$\text{Log}'\,r - \text{Log}'\,R' = \frac{R^2 - R'^2}{2\,R'^2}.\ \text{Log}'\,(R^2\,H - R'^2\,l) - \text{Log}'\,R^2\,H;\ \text{or},$$

$$\text{Log}'\,\frac{r}{R'} = \frac{R^2 - R'^2}{2\,R'^2}.\ \text{Log}'\,\frac{(R^2\,H - R'^2\,l}{R^2\,H}. \quad (6)$$

This equation can be written in the following manner:

$$\frac{r}{R'} = \frac{(R^2\,H - R'^2\,l)}{R^2\,H}^{\frac{R^2 - R'^2}{2\,R'^2}}.$$

The equation (6) can be written under another form more convenient for the study of the curve it represents:

$$\text{Log}' \frac{r}{R'} \frac{2R'^2}{R^2 - R'^2} = \text{Log} \frac{R^2 H - R'^2 l}{R^2 H},$$

or

$$\left(\frac{r}{R}\right)^{\frac{2R'^2}{R^2 - R'^2}} = \frac{R^2 H - R'^2 l}{R^2 H}.$$

This curve having for its axis of co-ordinates $o\,x$ and $o\,y$, r will be the abscissa and l the ordinate. Hence (see Fig. 12),

$$\left(\frac{x}{R}\right)^{\frac{2R'^2}{R^2 - R'^2}} = \frac{R^2 H - R'^2 y}{R^2 H}.$$

Discussion.—The nature of this curve varies with the exponent $\frac{2R'^2}{R^2 - R'^2}$. If $R'^2 = R^2 - R'^2$, or $R'^2 = \frac{R^2}{2}$, the curve is a parabola of 2d degree; if $2R'^2 = R^2 - R'^2$, or $R'^2 = \frac{R^2}{3}$, we shall have a right line. All quantities given to $2R'^2$ smaller than $(R^2 - R'^2)$, the curve will be a hyperbola, the degree of which is variable and becomes of the 2d degree, when $2R'^2 = -(R^2 - R'^2)$. But we should then have $R'^2 = -R^2$, which would give for R' an imaginary quantity.

Experimental Verification (Fig. 13).—The cylinder C is composed of two kinds of plates; the lower two occupying the total space having a radius R: those placed on top being rings, their exterior radius is R, and interior, $R' =$ to the orifice $= 0\,5$ of an inch.

Experimental Verification.

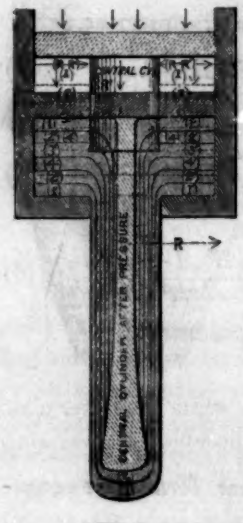


Fig. 13.

In this open space having a radius R', M. Tresca placed a cylinder of lead exactly fitting (this representing the supposed central cylinder). After the pressure had been exerted, a vertical section was made through the cylinder C and the jet; thus permitting a comparison between the theoretical equation and the actual fact.

In all the experiments made by M. Tresca, no difference greater than $\frac{1}{30}$ of an inch was found.

This verification is a strong proof of the exactness of the theory of the flowing of solids.

CERAMICS.

[Abstract of the closing lecture in Prof. Pliny E. Chase's course on "Lessons of the Centennial," delivered before the Franklin Institute, March 20th, 1877.]

One of the most important results of the London "World's Fair," in 1851, was the establishment of the South Kensington Museum. Liberal contributions having been made for the purchase of artistic works which would be typically representative, and æsthetically instructive, the attention of the directors was immediately and instinctively turned to the nations of Eastern Asia. Living near the birthplace of civilization, trained by long ages of unquestioning faith in the simple intuitions of taste, feeling and daring, rather than deliberating and contriving, the Mongolian artists had been educated, by the "second nature" of habit, to a remarkable delicacy of judgment in the harmonious blending of colors, and in the expression of ideals by graceful or appropriate forms.

The readiness with which ceramic[1] wares can be moulded and painted, rendered them fit vehicles for the display of artistic skill. We accordingly find, in all ornamental collections of Chinese and Japanese goods, that articles of china and porcelain hold a prominent place. It is, however, by no means certain that the earliest crockery was Asiatic. Potsherds have been found in Egypt at a depth of 39 feet below the surface, and some geologists, judging from historical data bearing upon the rate of the Nile deposits, have assigned them an antiquity of 13,500 years. The uncertainty of such estimates is shown by the late discussion between eminent geologists and astronomers, the former claiming at least a hundred million years since the deposition of the oldest rocks of the globe, while the latter claim that fifteen million years is the greatest supposable interval since the earth began to condense from the primitive nebular chaos.

[1] From the Greek word *Keramos*, "potter's clay;" *Kerameikos*, "made of clay."

Even among the most savage tribes of men, wherever there was a clayey soil, its plasticity and its property of hardening in the sun must have been early observed. Cooking utensils, when exposed to the fire, would be still further hardened, so that the potter's art may have grown from a number of independent centres. We find it recorded in Genesis, xi, 3, that the people "said one to another, Go to, let us make brick, and burn them thoroughly." This is supposed to have been about 2247 B. C., and we may probably assign to the same period many of the Assyrian and Babylonian tiles and cylinders which have been discovered within the last half century, some of which served as books for circulation, or for library reference, some as records of land titles, or of historical events, some as evidences of bankers' credits, or as currency for effecting exchanges in the channels of trade. The "cuneiform," or wedge-shaped letters of the old Assyrian and Persian alphabets, owe their peculiar configuration to the ease with which they could be cut by the graver in the soft clay. Earthen vessels are expressly mentioned in Leviticus, vi, 28, and xi, 33, about 1490 B. C. Some of the early Phœnician vases, which display much grace of outline and tasteful ornamentation, are assigned to the same period.

In common pottery, the clay is mixed with marl or sand before being baked. The usual red color is due to minute portions of iron ore, which oxidize in the fire. Pipe-clays, and such as are used for the Milwaukee brick or for firebrick, are free from iron, and they are therefore whitish or cream-colored after being burnt. The earliest forms of earthen vessels appear to have been derived from gourds, and some antiquarians have amused themselves

by searching out the particular species which have been most often copied in different nations. At first the moulding was done by hand, as in this mummy-vase from the Ibis pyramid of Sakkara, and in this Cherokee dinner-pot. But at a very early period, the potter's wheel was invented, from which Jeremiah drew his instructive lesson: "Then I went down to the potter's house, and behold, he wrought a work on the wheels; and the vessel that he made of clay was marred in the

hand of the potter: so he made it again another vessel, as seemed good to the potter to make it." On Egyptian monuments which are supposed to be nearly 4000 years old, the potter's wheel is depicted, of the same form as is used at the present day.

Messrs. Galloway & Graff have kindly sent us one of their wheels, with skilful workmen to perform the operation of "throwing" or shaping jugs, vases, and crocks of various kinds. See, as the wheel spins round, under the impulse of the treadle, how the shapeless mass of clay follows, as if by magic, the dexterous fingers of the craftsman, until, almost with the speed of thought, the finished vase stands before you in all its beautiful symmetry. See, also, as he cuts this jug in two with his slender wire, how uniform is the thickness of the clay, and how closely the inner and outer surfaces correspond in all their details of form. See, again, as new forms start into being, more swiftly than my words can follow them, how the vessel that was marred is made "again into another vessel, as seemed good to the potter to make it."

Although modern ingenuity has been unable to improve the potter's wheel, it has devised some useful subsidiary processes. Thus, with a turning lathe, the operation of "shaving" may be performed, not unlike the process of spinning metals, that I described to you in my last lecture, yielding more intricate shapes than can be readily got from the simple wheel; by "pressing" into plaster moulds, as the journeyman is now doing in this mould for a hanging basket, copies of approved works can be easily multiplied to any desired extent, and exquisite statuettes, like this reduction of the Venus of Melos, or fac-similes of the most graceful antique vases, like those upon the table, can be brought within the reach of moderate purses; by carefully selecting, drying, pulverizing and sifting the clay, and mixing it with gum water, a plastic paste may be formed of peculiar delicacy and tenacity, fitted, like wax, for the representation of fruits and flowers in their minutest details. The workman, as you see, first dips his fingers in oil, in order to prevent the adhesion of the clay, and then deftly shapes stem and stamen, and petals and leaves, until presently the completed flower is seen, delightfully representing some of the most beautiful forms of nature, with all their grace and expressiveness. Place this gray handiwork in the kiln, until the

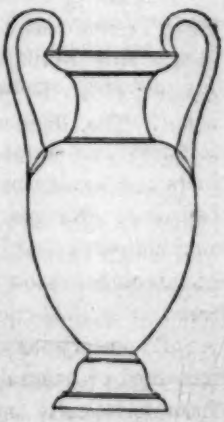
fire permanently imparts a portion of its own ruddy glow, and you will have a bouquet fit for the table of a queen. You have all, doubtless, been gratified with the evidences, already furnished by our shop windows, of the educating influences of the Centennial. I am sure that your gratification will be increased by finding that the good taste of our manufacturers is turning them to such practical account.

Ceramic or fictile wares are classed as "soft" or "hard." The former division embraces all of the earliest forms of pottery, terra cotta, and such earthenware, of any description, as can be readily cut or scratched by a knife; the latter includes stoneware, queensware, porcelain, and other similar wares which have a steel-like hardness. In each division there are various degrees of hardness, depending partly upon the materials, partly upon the degrees of heat to which the articles are exposed in the kiln. In my first lecture, I described glass to you as being both a salt and a soap, and I gave you ocular demonstration of its use in the latter capacity. Pottery may be regarded, in a similar manner, as sand soap, for it consists of alkaline silicates, with a mechanical mixture of earth or sand. One of our most valuable artificial cements, common mortar, is, like pottery, an alkaline silicate, being mainly a silicate of lime. The thoroughness with which the ingredients are blended, and the hardness and durability of the result, are well shown in the aqueducts and sewers of Rome, which have stood since the days of the Tarquins. Nature, in some of her most valuable gems, has effected combinations closely analogous to those which our best ceramic manufacturers seek to accomplish by the more speedy action of their fires.

Soft pottery may be either unglazed, glazed, lustrous, polished, varnished or enameled. These distinctions are most strikingly and characteristically marked, in the Etruscan or Græco-Roman *fictilia*, made between 800 B. C., and 350 B. C. The most beautiful forms are supposed to have been borrowed from Asia, and with good reason, as you may convince yourselves, by comparing the fac-similes of

vases found by Dr. Schliemann in the supposed ruins of Troy, with the vases upon the table. The ground was most often reddish brown, but sometimes fawn-colored, orange, ashy gray or black; the two latter colors being, perhaps, attributable to asphaltum, the others to iron. The ornamental figures were white, black, brown, red or yellow, consisting, in some of the most highly valued specimens, of mere outlines, scratched in the clay with a pointed instrument. In the best periods, and in the most satisfactory work, they were never raised above the surface, the pure taste of the designers shrinking from anything that would mar the severe dignity of the outline. The Greeks struck medals and erected statues to ceramic artists. The greatest sculptors and the noblest architects worked with potters, and designed for them; therefore, many of the sculptured, and some of the painted vases, were among the most justly prized works of the highest art that the world has ever seen.

Glazed or enameled surfaces, like this image of a mummy, were made in Egypt as early as the 4th dynasty, between 2000 and 3000 years B. C. You have all heard the story of the Phœnician sailors, who kindled a fire on the beach to cook their dinner, and, after it was over, found glass in the ashes. The tale is likely enough, for beach sands are commonly siliceous, and sea-weeds abound in soda, so the materials and the heat that were needed to make silicate of soda, or glass, were at hand.



But the discovery may have been independently made, in many different times and places. The yellow color of lamp-flames is mainly owing to the soda that is in the flame. Bricks and pots are often glazed when the heat is intense, without any special preparation. The simplest mode of glazing is by throwing a little salt into the kiln. The salt is decomposed by the heat, its chlorine escapes, and the soda remains in a state of vaporous diffusion, just in a fit condition to open new combinations and assume new orbits of oscillation. It therefore readily unites with the silicon

of the clay, and forms a transparent glass surface. Enamels with metallic oxides, copper for blue, and tin for white, were used on bricks and vases at a very early date in Babylonia and Assyria, and some Chinese writers claim the manufacture of porcelain, as early as 3200 B. C. Stanislaus Julien, however, thinks this was merely stoneware, and that there are no authentic records of any porcelain resembling the modern wares, earlier than 185 B. C. It is not unlikely that the arts of cloisonné and champ levé enameling may have been known at a much earlier date.

Philostratus, a Greek, who established himself in Rome in the early part of the 3d century, at the wish of Julia, wife of Septimius Severus, in his "Treatise on Images," writes: "It is said that the barbarians living near the ocean, pour colors upon heated brass, so that they adhere, become like stone, and preserve the design represented." The Castellani collection contained exquisite specimens of ancient enamels; the Italian and French departments, and especially the exhibits from Limoges, of modern enamels. The *champ levé* process, in which the ground for the paste is cut out of the solid metal, leaving slender outlines for the design, seems to be more modern than the *cloisonné*, and much less difficult. The best works of this kind were executed in the 12th century. The Japanese appear to have improved upon their teachers, the Chinese, by cementing the cloisonné filigree to a porcelain body. The Chinese, French and English, have all successfully adopted the improvement, and Elkington's porcelain cloisonnés left nothing to be desired, either for perfect execution, taste of design, or harmony of color. The Hindoos are still wonderfully proficient in the art of enameling on metals.

The Saracens brought to Europe the secret of applying enamel colors to tiles and vases, using both the transparent lead and the opaque tin enamels. They conquered the Balearic Isles in 798, and established potteries in Majorca, which was conquered by James I, King of Aragon, in 1220, and united to Spain in 1375. The manufacture of pottery was continued under Christian rule, and the ware was called majolica, from the name of the island. All true majolica is "soft," the resemblance to harder wares being due to the opacity of its enameled surface. About A. D. 1430, Luca della Robbia cast his large circular *rilievos* and statues in potter's clay, fired and glazed them, and applied them as sculptures to Florentine buildings.

The first period of majolica proper, or mezzo-majolica, was from 1450 to 1500. The forms and ornamentation were stiff and often grotesque. During the second period, from 1500 to 1560, the wares reached their highest excellence, the most celebrated factories being at Pesaro, Gubbio, Castel Durante and Urbino. In 1509, Jacques Lanfranco, of Pesaro, received from the Duke of Urbino, his patent for "the application of gold to the Italian faience,"[1] giving a peculiarly brilliant prismatic lustre. In 1511, and subsequently, "Maestro Giorgio" Andreoli of Gubbio, improved upon Lanfranco's invention, giving his wares an inimitable ruby glow; but the secret of his process died with him. Near the close of the period, finer clays were used, more care was observed in all the processes of manufacture, and the name "porcellana," signifying "little pig," was given to the product. This name is said to have been first applied to cowrie shells, from the resemblance of their shape to a pig's back, and transferred to the majolica on account of its beautiful white shell-like gloss. This early porcellana is sometimes called Raffaelle ware, from the idea that the great artist decorated the plates with his own hands, but the earliest specimens were not made until about twenty years after his death. Many of his designs, however, as well as those of Julio Romano and Marc Antonio, were employed, together with graceful figure compositions from the Bible and old mythologies, often surrounded by imaginative arabesques.

During these two periods an earthenware with a strong green glaze was manufactured in Germany (A. D. 1473); a very cheap, gaudily colored, rudely designed, but serviceable ware, at Delft, in Holland (A. D. 1500); the fine French Oiron or Henri-Deux ware, of which less than forty specimens are believed to be in existence (*ca.* A. D. 1520); and the Palissy ware. You know the story of Bernard Palissy; the poverty and misery and repeated failures that saddened his humble home at Saintes; the sixteen years of patient experiment, marked and sustained by a courage which did not flag even when he was obliged to burn his furniture in order to feed his furnaces; the

[1] A term supposed to have been derived either from Faenza in Italy, or from Fayence in France.

sturdy independence of his determination to work out everything for himself, though he might have learned much from the Italian factories; the beautiful forms, exquisite ornamentation, and close imitation of nature, which ultimately brought him the highest patronage, in spite of the inferiority of his material and the frequent coarseness of execution.

The hard pottery is sometimes divided into fine earthenware and stoneware. The semi-transparent variety, which was made in China at a very early date, is thought to have reached perfection about A.D. 1000. Its manufacture was described by Marco-Polo, in the fourteenth century, but it was not generally introduced in Europe until the Portuguese began trading with China, early in the sixteenth century. The principal ingredients used in the paste, are called by the Chinese "kao-lin" and "pe-tun-tse," both of which are forms of feldspar; the former being decomposed and of a clay-like texture, the latter crystalline. They consist mainly of silex and alumina, which, when partially fused, form a glass that cements the unfused particles and gives translucency to the whole. The decomposition of the kaolin is, perhaps, owing to a crystallization established at considerable depths and high temperatures. The conditions of expansion and tension being consequently different from those usually observed, the whole mass was subjected to an abnormal strain, somewhat like that of the Prince Rupert's drops. When, by subsequent convulsions, the primitive metamorphic rocks were lifted to the surface, the change of conditions favored disintegration and a readjustment of particles, which might lead either to new crystallizations, or, if the moisture was sufficient, to the formation of clayey beds.

The Japanese appear to have established porcelain factories at or about the mezzo-majolica period. Borrowing their methods and processes from the Chinese, their quickness of perception made them good imitators, both of art and of nature. Hence a comparison of their early wares, with the Chinese wares of the same date, shows the difference between naturalism and conventionalism, between life and death, between originality and imitation, between idealism and traditionalism. The works at Hizen, Kaga, Kioto, Satsuma, and

Yeraku were represented at the Centennial by samples of Some-Tsuki, or blue ware painted with cobalt oxide under the glaze; Kanyu, Hibiki or "Craquelé"; Seidji, or Seladon; Akai, or red ware; and Gosai, or Nishikide, painted with vitrifiable colors upon the glaze. The Kanyu was curious, but very little of it had any artistic merit.

The cracks with which the surface is covered, are due to differences in the rate with which the glaze and body of the ware contract in cooling, a difference which was at first accidental, and afterwards intentionally imitated, by selecting ingredients which would uniformly produce similar results, and gratify the taste of the merely curious. Some of the Satsuma "craquelé," however, was so fine as to produce a peculiarly pleasing crape-like effect, as you may see by the jug on the table.

The first manufactory of European porcelain was erected by Augustus II, at Meissen, on the Elbe, about A. D. 1698. He had employed John Frederick Böttcher, a reputed alchemist, to conduct researches for his benefit. In the preparation of crucibles that would stand an intense heat, Böttcher found a clay that made a fine red ware, similar to the Japanese Akai. Noticing, one morning, that his wig was very heavy, he found that his valet had used a new hair-powder, which had been introduced by a wealthy iron-master, whose horse's feet had one day stuck fast in a bed of white mud. The mud, when dry, yielded a fine powder, which made a cheap substitute for the wheat flour, then used for hair-powder. Böttcher found, upon analysis, that this was precisely what was needed for making the finest white porcelain. The workmen were sworn to secrecy, but the process gradually leaking out, factories were established at Berlin, Vienna, Höchst, Naples and Sèvres.

In England, A. D. 1710, two brothers, by the name of Elers, from Nürnberg, made a fine pottery, by a secret process, at Burslem, in Staffordshire. A potter, by the name of Astbury, counterfeiting idiocy, learned the art, and drove out the Elerses by his competition. Works had been previously established in Fulham, Chelsea, and Bow. About 1760, Josiah Wedgwood began imitating agate and tortoise shell in the manufacture of porcelain knife-handles and various ornamental articles. He sent a service of cream-colored ware to Queen Charlotte, who was so much pleased with it that he

called the ware, at her request, "Queen's Ware." Wedgwood's copies of the Portland Vase and other antiques, together with his original productions, which were embellished by Flaxman, soon gave him a world-wide and lasting fame. His reputation stimulated others, and successful works were established at Derby, Plymouth, Bristol, Worcester and Lowestoft. The wares of Minton and Copeland compare favorably with those of Dresden and Berlin, both in quality and in ornamental decoration. The Lambeth Faience, or Doulton ware, which deservedly attracted so much attention at the Centennial, is a reproduction of the "Grès Cérame," or "Grès de Flandres," resembling some of the earliest known Chinese stoneware. The raised decorations are made by pressing clay into moulds, as in the old Samian ware of Greece. By combining the ornaments in relief with indentations of bold lines and patterns, engravings by incised lines, and surface painting or printing, all necessity for duplication is avoided, and various artistic articles of daily use are produced at a moderate cost.

If this rapid survey of the ceramic art has recalled to your minds any features of the Exhibition, which you might otherwise have forgotten, if it has helped towards satisfying your curiosity upon any points, or if it has shown you that the Centennial was a school of even more abundant teaching than you had imagined, my object has been accomplished. In these three lectures, I have directed your attention only to a few of the most obvious lessons, but I trust they have sufficed to show you the importance of mutual helpfulness, among nations as well as among individuals; the advantages of high ideals towards which artisans and artists alike may work; the superiority of the spiritual over the physical nature of man; the inheritance of common aspirations and common destinies, which is never more manifest than in International Exhibitions, where "one touch of nature makes the whole world kin."

[The illustrations, in this report, were loaned by Messrs. Galloway & Graff, 1725 Market street. The vases are all copies of antique designs.]